The University of Adelaide

REPORT

of the

WAITE AGRICULTURAL RESEARCH INSTITUTE

SOUTH AUSTRALIA

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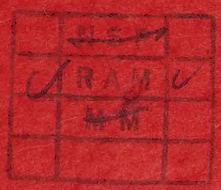

1960-61

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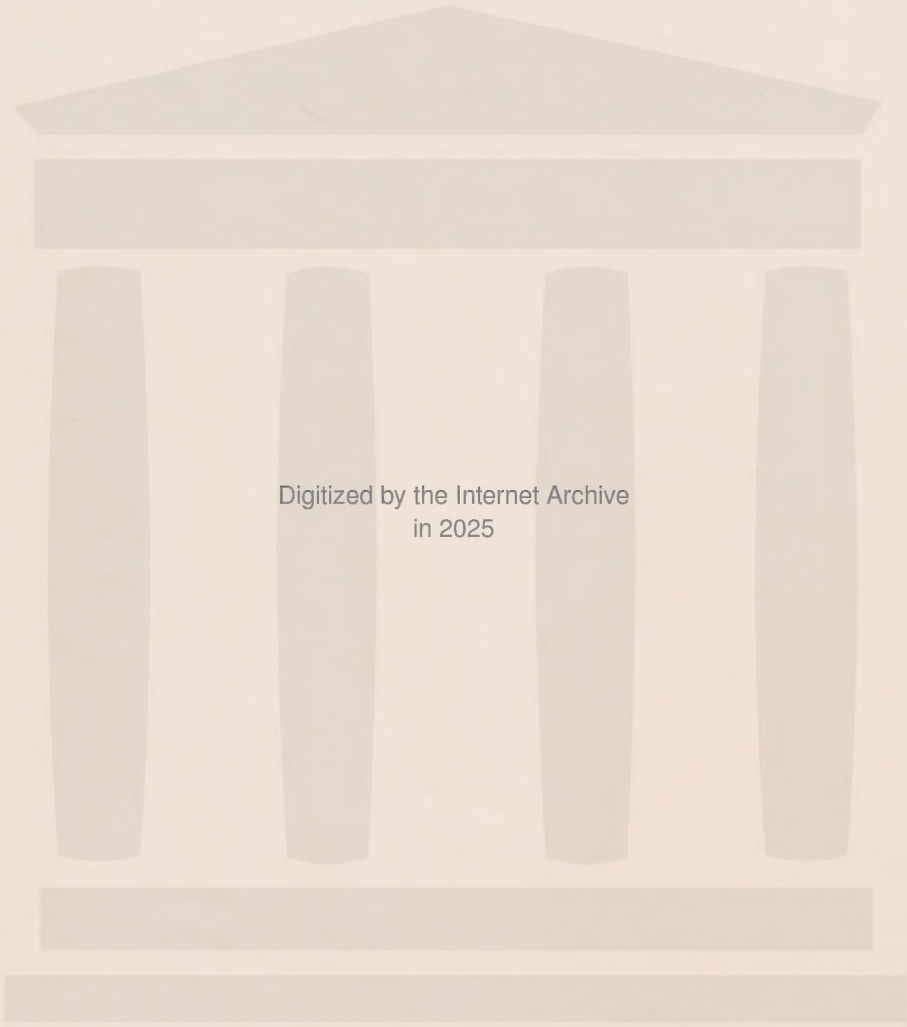

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The University of Adelaide

REPORT

of the

WAITE AGRICULTURAL RESEARCH INSTITUTE

SOUTH AUSTRALIA

1960-61

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The University of Adelaide

VISITOR:

His Excellency the Governor.

THE COUNCIL AS AT 31st DECEMBER, 1961.

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W. M. C. Symonds, B.Sc., Dip.Ed.

Professor J. R. Trevaskis, M.A.

Annie W. Wall, M.B., B.S., F.F.A., R.A.C.S.

V. A. Edgeloe, B.A., Registrar.

The Waite Agricultural Research Institute

STAFF (*at 31st December,* 1961).

Director: J. Melville, M.Sc., Ph.D.

Agricultural Chemistry:

Waite Professor of Agricultural Chemistry and Head of Department: R. K. Morton, B.Sc.Agr., Ph.D., F.A.A.

Agricultural Biochemistry:

Senior Lecturers: A. Adele Millerd, M.Sc., Ph.D.
M. R. Atkinson, B.Sc., Ph.D.

Lecturers: Janet S. D. Graham, B.Sc., Ph.D. (Comm. Wheat Ind. Fund).
I. R. Falconer, B.Sc., Ph.D.

Technical Officer: Kathryn F. Shepley, B.Sc. (McGregor Reid Cancer Fund).

Soil Science:

Reader: J. P. Quirk, B.Sc.Agr., Ph.D.

Lecturers: D. J. Greenland, M.A., D.Phil. (State Wheat Fund).
A. M. Posner, B.Sc., Ph.D.
D. G. Lewis, M.Sc.

Virology:

Reader: R. J. Best, D.Sc.

Lecturer: H. P. C. Gallus, M.Sc.

Analytical:

Lecturer: A. C. Jennings, B.Sc.

Laboratory Steward: H. R. J. Lovelock.

Technical Assistants: B. A. Palk, E. J. Frederick, T. W. Sherwin, H. L. Nicholls, R. E. Griffiths.

Laboratory Assistant: P. C. Lee.

Junior Laboratory Attendants: R. Connelly, C. A. Adams, R. E. Langman, A. Nagy, U. Heinzle, D. Morton, Lois Cornish, Margaret Ryder, R. M. Lilley, F. C. Rundle, C. J. Hulse, T. W. Cock, R. Langham, M. K. Hollister.

Post-Doctoral Visitors from Overseas: L. T. Kurtz, C. D. Ramakrishnan, I. A. Hansen, J. B. Hanson.

Junior Fulbright Scholar: G. Lindstrom.

Agronomy:

Waite Professor of Agriculture and Head of Department: C. M. Donald, M.Ag.Sc., F.A.I.A.S.

AGRONOMY (*continued*)

Plant Breeding and Crop Genetics:

Reader: K. W. FINLAY, B.Sc. (Agric.), Ph.D.

Lecturers: R. KNIGHT, B.Sc. Dip.Ag.Sc., Dip.Trop.Ag. (I.C.T.A.).
D. H. B. SPARROW, B.Sc. (Barley Imp. Fund).
K. W. SHEPHERD, B.Ag.Sc. (Comm. Wheat Ind. Fund).
K. MOORE, B.Sc. (Comm. Wheat Ind. Fund).

Crop and Pasture Ecology:

Reader: J. N. BLACK, M.A., D.Phil.

Lecturers: E. D. CARTER, B.Ag.Sc.
J. H. SILSBURY, M.Sc.Agr.
J. A. CARPENTER, M.Sc.Agr.

Plant-Soil Relationships:

Senior Lecturers: K. P. J. BARLEY, M.Sc.Agr.
R. J. MILLINGTON, M.Sc., Ph.D.

Lecturer: J. K. POWRIE, B.Sc.Agr., M.Sc.

Animal Production:

Senior Lecturer: W. G. ALLDEN, M.A., M.Ag.Sc. (Mortlock Fellow).

Lecturer: G. C. EVERITT, M.Sc. (Wool Research Fund).

Botany:

Lecturer: D. E. SYMON, B.Ag.Sc.

Senior Technical Assistants: E. J. LEANEY, M. J. BARGE, V. KISIS.

Technical Assistants: A. V. LEHMANN, A. SIRMAIS, J. W. CHIGWIDDEN, R. W. MALLEN, I. D. RIDGEWAY, D. J. WILLIAMS, R. HULA, J. MALONEY, S. RICHARDSON, R. D. PEARCE.

Laboratory Assistants: A. G. W. HEWSON, BARBARA L. DENTON, R. A. GIBSON, M. J. GRAY, IRMA BUMBIERIS, S. N. CHO.

Junior Laboratory Attendants: H. LYSBETH HANNS, J. D. BURTON, MARGARET C. HALLETT, MAUREEN F. LEAN, K. G. WILLIAMS, JENNIFER R. WILLINGTON, CAROLYN M. SNOWDEN, PETRELLA M. KEMP.

Post-Doctoral Visitors from Overseas: W. A. WILLIAMS.

ENTOMOLOGY:

Waite Professor of Entomology and Head of Department: Vacant.

Forest Entomology:

Senior Lecturer: F. D. MORGAN, M.Sc., Ph.D. (Acting Head of Dept.).

Morphology/Systematics/Insect Pathology:

Senior Lecturer: H. S. F. LOWER, M.Sc.

Assistant Systematic Entomologist: HELEN M. BROOKES.

Aphidology:

Senior Lecturer: B. JOHNSON, B.Sc.Agr., Ph.D.

Apiculture:

Lecturer: K. M. DOULL, M.Ag.Sc.

ENTOMOLOGY (*continued*)

Insect Ecology:

Lecturers: D. A. MAELZER, B.Sc., Ph.D. (Codling Moth Invest.).
D. J. TAYLOR, B.Sc., Dip.Ag.Sc., Dip.Trop.Ag. (Lucerne Insects) (Wool Research Fund).

Research Fellow: A. G. BASSON, B.Ag.Sc. (Insects of Fodder Crops) (Wool Research Fund).

Physiology of Hemiptera:

Lecturer: P. W. MILES, M.Sc., Ph.D.

Fruit Fly Investigation: (Sydney):

Lecturer: J. MONRO, B.Sc., Ph.D.

Technical Assistants: N. C. STEWART, D. J. LAMBERT.

Laboratory Assistants: COLLEEN M. HILL, ANNA DUBROWSKY.

Junior Laboratory Attendants: R. IRVING, KAY C. SCHILLING, VONDA M. STACE, MARIE MCCANN (Sydney).

PLANT PATHOLOGY:

Reader and Head of Department: N. T. FLENTJE, M.Sc., Ph.D.

Soil-borne Fungi:

Senior Lecturers: J. H. WARCUP, M.Sc., Ph.D.
A. KERR, B.Sc., Ph.D.

Technical Officer: HELENA M. STRETTON, B.Sc.

Air-borne Fungi:

Lecturer: M. V. CARTER, M.Ag.Sc.

Virology:

Lecturers: N. C. CROWLEY, B.Sc.Agr., Ph.D.
R. I. B. FRANCKI, M.Sc., Ph.D.

Fungal Physiology:

Lecturer: B. G. CLARE, B.Sc.

Systematic Mycology:

Senior Lecturer: P. H. B. TALBOT, M.Sc., Ph.D. (Dept. of Health).

Forest Pathology:

Lecturer: L. O. VAARTAJA, Ph.D.

Nematology:

Lecturer: J. M. FISHER, B.Sc.Agr.

Seconded from C.S.I.R.O.: A. BIRD, M.Sc., Ph.D. (Sen. Res. Officer).
B. JEFFERY (Technical Assistant).

Research Fellows: B. H. PRATT, B.Sc.Agr. (Pea Research).
R. DODMAN, B.Ag.Sc. (Comm. Wheat Fund).
J. F. BURDETT, B.Ag.Sc. (Stone Fruit Invest.).

Senior Technical Assistant: S. R. HOCKLEY.

Technical Assistant: LEA WICHMAN.

Plant Pathology (*continued*):

Laboratory Assistants: G. J. Ford, K. W. R. Crocker, M. Bumbieris, R. J. McGuire, G. E. Campbell.

Junior Laboratory Attendants: Pamela Browne, Helen Hughes, Janice A. Roberts, Mary R. Roberts.

Post-Doctoral Visitors from Overseas: K. Baker, T. Kommedahl, A. F. Posnette, W. Snyder.

Plant Physiology:

Reader and Head of Department: L. H. May, B.Sc., Ph.D.

Lecturers: N. G. Marinos, M.Sc., Ph.D.
L. Paleg, B.A., Ph.D.
D. Aspinall, Ph.D. (Barley Imp. Fund).

Horticulture:

Lecturers: G. R. Edwards, M.Sc., B.Ag.Sc.
B. G. Coombe, Ph.D., M.Ag.Sc.

Research Fellow: M. S. Buttrose, B.Ag.Sc., M.Sc., Dr.Sc.nat. (Comm. Wheat Ind. Fund).

Technical Officer: Fay H. Chapman, B.Sc. (Aust. Atomic Energy Comm.).

Technical Assistant: A. W. Zanker.

Junior Laboratory Attendants: Felicia H. Smith, Carol Brownson, Julie A. Whitmarsh.

Biometrics:

Reader: Professor E. E. Remmenga (visiting on Sabbatical Leave from Colorado University).

Laboratory Assistant: D. L. Messent.

Clerical and Library Staffs:

Secretary: G. L. Gooden.

Librarian: Shirley J. Susman, B.Sc.

Assistant Librarian: Jennifer A. Prest, B.A.

Library Assistants: Helen F. Morris, Ruth E. Johnson, Elizabeth J. Rees.

Secretary to the Director: Laureen G. Downie.

Secretary/Typistes: Marjorie Young, Shirley M. Mulcahy, Beatrice H. Hosking, Margaret E. Kavanagh, Judith S. Dennison.

Typistes: A. Anne Brown, Pauline A. Coulls, Jenifer J. Part, Joan Smith.

Telephoniste: Betty J. Langman.

Clerks: K. H. Davies, C. S. Leaney, J. G. LeMercier.

Photographer: K. P. Phillips, A.R.P.S.

Junior Laboratory Attendant: Patricia J. Rose.

Cartographer: P. D. Hooper.

Farm:

Manager: K. A. Pike, R.D.A.

Senior Technical Assistant: D. B. Steen, R.D.A.

Technical Assistant: A. W. Dick.

Head Gardener: F. A. Couzens.

Members of Staff Absent on Study Leave during 1960-61: J. Melville, M. R. Atkinson, J. N. Black, K. P. J. Barley, J. H. Silsbury, W. G. Allden, H. F. Lower, K. M. Doull, L. H. May, J. M. Fisher.

Post-Graduate Students: J. R. Wells, R. Laby, J. F. Jackson, J. B. Taylor, P. B. Nicholls, D. W. Puckridge, K. Santhirasegaram, I. Whittaker, V. D. Wasserman, D. G. Edwards, K. G. Theng, P. Caiger, T. L. Deshpande, N. S. Scott, A. W. Murray, D. E. Bottrill, J. R. Burford, R. Naylor, D. Muljadi, J. W. Randles, Taty Djajakasumah, D. I. Jackson, J. Vicens, W. R. Stern, L. Moniz, S. Chun, J. K. Raison, D. H. Symons, B. K. Taylor, J. Radcliffe, D. Montague.

Members of Staff who have Left for Other Appointments since January 1st, 1960: D. H. Simmonds, J. W. McGarity, L. D. Crawford.

Deceased: D. C. Swan, K. Abele.

The Waite Agricultural Research Institute

1. Introduction

Earlier reports gave an account of the foundation of the Institute through the gift of land and money by Mr. Peter Waite, and of the subsequent gifts and bequests which have played so significant a part in its development.

During the period under review the complex of buildings for the C.S.I.R.O. Division of Soils was completed, and the Sections of Soil Physics and Soil Microbiology moved to their new accommodation in November, 1961. With the completion of the transfer of C.S.I.R.O. staff from the main building of the Waite Institute, a physical association which dates back to 1928 and which has been most productive in terms of agricultural progress, comes to a close. However, although the Division of Soils and the Australian Wine Research Institute now have their own buildings, they are still housed within 300 yards of the main Waite Institute laboratories; and it is gratifying to know that the intellectual association is as strong as ever.

The space vacated by C.S.I.R.O. has enabled a doubling of the very inadequate space previously available to the Library, the extension of laboratory space for the Departments of Agricultural Chemistry and Agronomy, and provision of space for the Department of Animal Physiology which is in process of establishment. The Institute has also added to its physical facilities a 12-unit insectary with ancillary working space, two glasshouses, a solvent store, and lunch and washrooms for farm staff.

2. The Teaching Programmes

Teaching in the first and second years for the degree of Bachelor of Agricultural Science in the University of Adelaide is given by Science Departments at the North Terrace campus. This is followed by third, fourth and fifth (honours) years at the Waite Institute, where courses are given in the following subjects: Agricultural Biochemistry, Agricultural Botany, Agriculture, Agronomy, Biometry, Entomology, Horticulture, Microbiology, Plant Breeding, Plant Pathology and Soil Science. Certain subjects, of which the most important is Animal Production, are taken at the Roseworthy Agricultural College.

Honours and postgraduate teaching is undertaken by all five Departments, and the numbers of candidates for higher degrees continues to increase. Thus in 1961 eight students completed the honours degree, sixteen postgraduate students were working towards the degree of Doctor of Philosophy and ten (including those working externally) for the degree of Master of Agricultural Science.

3. The Research Programme

The research programme of the Institute extends over a wide range of scientific disciplines underlying agricultural practices. Much of the work has its immediate origins in problems of significance in southern Australia, but the pursuit of these problems commonly carries the research into basic fields of general agricultural significance.

The major part of the programme is financed through grants to the University by the Government of South Australia, but as noted in recent reports direct financial support from various sections of the agricultural and pastoral industries becomes increasingly important. Approximately one-quarter of the research programme in 1961 was financed in this way, the major contributors being the Wool Research Committee, the Wheat Industry Research Council and State Committee and the Barley Improvement Committee. In addition to these funds which are derived from the whole Commonwealth, local associations of vegetable and fruit growers have imposed levies on production for the investigation of particular problems.

The Institute also continues to receive financial support for specific purposes from a number of foundations, commercial firms and individuals, and support in other ways from large numbers of co-operating farmers and graziers. It is impossible to list all their names, but it would be not invidious to single out the Rural Credits Division of the Reserve Bank, the Rockefeller Foundation, the Anti-Cancer Fund, the Nuffield Foundation and the Squibb Institute for Medical Research.

The research work of the Institute is organised within five departments: Agronomy, Agricultural Chemistry, Entomology, Plant Pathology and Plant Physiology, and the work of each of these departments is recounted in the following pages of the Report. The Institute also provides specialist advisory services in systematic botany, plant pathology and entomology to the State Departments of Agriculture and of Woods and Forests. These services, which are described in the relevant Sections of the Report have reciprocal value to the Institute because they draw attention to agricultural and forestry problems which have direct practical application and which require fundamental investigation.

The library continues to expand and now includes 16,000 books and subscriptions are paid for over 500 periodicals. Back numbers of much-used periodicals have been purchased thus completing many journals in our library. In the last two years the volume of inter-library loans has more than doubled, and in particular there has been a notable increase in the number of requests to the Institute for the loan of periodicals and books.

The Work of the Institute

Agronomy

The work of the Department is concerned with the ecology and breeding of crops and pasture plants, and with the nutrition of sheep in the field. Although the answers to many agricultural questions have to be obtained empirically, the work of the Department is continually reducing the degree of empiricism required in agricultural experimentation. For example, an understanding of the influence of plant competition on the comparative performance of different varieties of crop and pasture plants has permitted better definition of the conditions under which varieties can be validly compared. Collaboration with workers in the narrower disciplines is being fostered, and cooperative investigations have been conducted during 1960-61 with workers in the fields of biochemistry, physiology, genetics and soil physics. The unifying factors in the work of the Department are the interest in performance in the field and the foundation of the methods of investigation in Fisherian statistics. In applying statistical methods to a large volume of data obtained in plant breeding and certain ecological investigations, early use has been made of the computers which have recently been made available for biological work at the Computer Centre of the University of Adelaide and at the Weapons Research Establishment, Salisbury, South Australia.

The first demonstration of cobalt deficiency in plants in the field by J. K. Powrie in 1960 has added to the earlier and well-known achievements of Waite Institute workers in the diagnosis of micro-element deficiencies. Experiments on the interaction between soil moisture suction and soil strength suggest that current ideas on the influence of soil moisture stress on plant growth may have to be substantially revised to take account of the change in mechanical resistance offered to the extension of roots at different soil moisture contents.

The delineation of the conditions under which competition for light limits the rate of herbage growth is proceeding, and plant competition for light and nutrients has become one of the chief interests in the ecological work of the Department. Plant selection and breeding has produced promising hybrids between Mediterranean and Northern European varieties of cocksfoot (*Dactylis glomerata* L.). In the cereal breeding experiments micro-tests of quality for malting and bread-making are being employed very early in the breeding programme. The appointment of a wheat geneticist, wheat breeder, and barley breeder has enabled more intensive study of the wide range of cereal varieties and hybrids now available.

The investigations on the effects of the incidence of feed shortage on ewes and lambs have also been expanded, and a new biopsy technique is enabling more objective estimation of body growth. The residual effect of undernutrition in the pre-weaning period has been shown to be of long duration, significant effects still being apparent in the fifth year of life.

1. Permanent Rotation Experiment (C1)

(Mr. K. A. Pike)

A comparison is being made of ten systems of crop rotation in which the principal crop is wheat. A permanent pasture is also maintained to enable comparisons to be made of changes in the soil. The experiment, which was begun in 1925, is conducted on a red brown earth at the Waite Institute. The mean yields for 1926-61 (both grain and total produce) together with the yields for 1960 are given in Tables 1 and 2 on pages 68-71.

Several rotations, particularly those which include pasture leys, have been maintained only since 1949 and cannot yet be fully assessed. However, there is increasing evidence of the beneficial effects of including short-term leys in the rotation and of broadening the rotation. The following table shows the yields of wheat for the 1960 and 1961 seasons for several contrasting rotations.

Rotation	Yield of wheat (Bus. per acre)	
	1960	1961
Wheat continuously	22·1	6·0
Wheat, bare fallow	23·5	8·7
Wheat, peas	21·2	14·8
Wheat, oats, fallow	26·9	13·4
Wheat, pasture, fallow	35·4	11·2
Wheat, oats, pasture, fallow	51·9	20·6
Wheat, pasture, pasture*	44·3	21·3

*Commenced 1949. Other rotations commenced 1925.

2. Investigations of Plant/Soil Relationships.

The investigations deal chiefly with the response of wheat varieties and pasture legumes to changes in soil conditions.

(a) *Response of Wheat Varieties to Applied Nitrogen*

(Mr. K. P. J. Barley)

A field experiment has been conducted for four seasons to examine the ability of commercial varieties of wheat to utilize enhanced levels of nitrogen. The contrasting varieties Gabo, Javelin and Bencubbin have been grown at the Waite Institute with as much as 120 lb. per acre of nitrogen applied as ammonium sulphate at seeding. In 1958 heavy winter rains depleted the store of available nitrogen in the root zone, and the yield of tops and of grain were appreciably increased by moderate applications of nitrogen. An exceptionally severe drought occurred in 1959. In 1960 and 1961 winter rainfall was low and most of the applied nitrogen was retained within the root zone. Nevertheless, the yield of tops increased with the level of nitrogen. In the three seasons 1958, 1960 and 1961 application of nitrogen at the highest rate (120 lb. per acre) reduced the yield of grain. In 1958 and 1961 the period after ear emergence was dry, and earlier wilting on the high nitrogen plots led to the reduction in grain yield. In 1960 heavy rains during ripening were followed by lodging on the high nitrogen plots. The experiment indicates the kind of difficulties likely to be encountered when wheat is grown at high levels of nitrogen, and attention is being given to the management practices and varietal characteristics needed for the utilization of high levels of nitrogen.

(b) *Wheat Yields and the Interaction of Water and Nitrogen Supply.*

(Dr. R. J. Millington)

Previous reports have shown that wheat yield is greatly reduced at the Waite Institute by high rainfall in the month following seeding. Although the red brown earth used in the cereal experiment is coarse textured, it is moderately unstable and poor soil aeration is partly responsible for the decline in yield. Leaching of soluble nutrients beyond the roots of growing wheat plants may also be a factor in the decline in yield, and pot experiments have been conducted to further examine the importance of poor aeration and leaching. Wheat roots were temporarily deprived of air or nitrate for period of up to six weeks from the time of emergence. Withholding nitrogen for the first six weeks had little effect on the final yield of tops or grain, providing that adequate nitrate was supplied during the remainder of the growing season. Where aeration was impaired for periods of from two to six weeks by maintaining a high water content in the soil, the final yield of tops and of grain were reduced by about 15 per cent.

A field experiment conducted in 1961 compared the growth and yield of wheat grown at two levels of applied nitrogen, each with and without irrigation. Irrigation began after emergence and continued until heading. In this period the irrigation schedule was arranged to reproduce the incidence of rainfall which occurred in the 1955 season when a wet winter led to a low yield. Irrigation in the month following sowing led to a reduction in tiller number. However, later in the growing season, which was extremely dry, the difference in tiller number disappeared. By the dough stage the area of green leaf in the irrigated plots was much higher than the non-irrigated, and grain yield was greater in the irrigated plots.

(c) *Nodulation and Growth of Legumes in Acid Sands.*

(Mr. J. K. Powrie)

The establishment and growth of pasture legumes on certain acid, siliceous sands in the south-east of S.A. has been unsatisfactory in spite of correction of the known deficiencies. In 1960 it was shown for the first time in the field that subterranean clover responded significantly in terms of yield of dry matter and nitrogen to small dressings of a cobalt fertilizer. Work in 1961 confirmed the existence of cobalt deficiency in subterranean clover at this site, and, furthermore, revealed that lucerne suffered more severely from cobalt deficiency than did subterranean clover. These field results have followed closely on the discovery in the U.S.A. that trace amounts of cobalt are needed for symbiotic nitrogen fixation in legumes. Nodulated legumes relying on atmospheric nitrogen for growth are the only higher plants which have been shown to have an unequivocal need for cobalt. In the field, plants which were not nodulated or which were supplied with fertilizer nitrogen did not respond to cobalt.

The known beneficial effects of lime on nodulation of legumes grown on the sands is also being investigated. In 1961 it was found that lucerne was more dependent on both lime and inoculation for successful nodulation than was subterranean clover. The relative importance of calcium supply and pH change in determining lime response were studied. Some improvement in nodulation occurred when pH was raised from 5·6 to 6·3, but the principal effect of liming was shown to be due to an increase in calcium level in the soil.

(d) *Cation Requirements of Varieties of Subterranean Clover.*
(Mr. J. K. Powrie)

The cation requirements of subterranean clover varieties are being compared. Where heritable differences in cation requirements exist, there is scope for more efficient use of certain soils by the breeding or selection of varieties adapted to the level of nutrient supply. It has been found that subterranean clover has the ability to use sodium as a partial substitute for potassium, provided that the plant is not acutely deficient in potassium. Varieties differ appreciably in the extent to which they absorb sodium at low levels of potassium.

(e) *Chemical Fertility of Sandy Soils in South-Eastern South Australia.*
(Mr. J. K. Powrie)

The rate at which organic nitrogen accumulates when virgin soils in the region are sown to pastures and top-dressed is being measured, using samples obtained from fields of known history. The fate of applied phosphorus and sulphur is also being measured. A survey of properties, where accurate top-dressing records have been kept, shows that 50 to 60 per cent. of the phosphorus applied in superphosphate is retained in the top soil over a period of years. Most is retained in the top two inches of the soil. About one-half of the retained phosphorus is in an inorganic form, which is probably almost as good as superphosphate as a source of phosphorous for pasture plants. The residual phosphorus, as a whole, has about one-half the value of an equivalent amount of phosphorus in the form of superphosphate. It has recently been shown that withholding superphosphate may lead to the early appearance of sulphur deficiency in the sandy soils of the region. This appears to be due to the rapid transformation of applied sulphate to organic sulphur.

(f) *The Influence of Soil Strength on Root Growth and Seedling Emergence.*
(Mr. K. P. J. Barley)

The strength of soils can be characterised by measuring cohesion and friction parameters, and rough estimates may then be made of the resistance likely to be offered to a penetrating root or shoot. However, these or similar tests can scarcely be used to estimate the effects of soil strength on plant growth until more is known about the forces developed by growing roots and shoots, and about the effects of mechanical stress on growth. A laboratory apparatus has been developed for subjecting growing roots to a range of stresses. In one experiment the apex of the root was compressed in a way that permitted the cells to elongate and differentiate while subject to stress. Growth in length proceeded without interruption when the roots were stressed, although at a reduced and continuously declining rate. In another experiment lengths of roots which had differentiated before the load was applied were compressed. Growth in length stopped for a number of hours and was then resumed at a low rate. The compression of older tissue is thus more harmful than the compression of the growing tip. The older parts of roots are often compressed in field soils by the swelling action of wetting clay.

Effects of soil moisture content on plant growth are usually attributed to changes in the availability and supply of water. However, the effects of the negative pressure in the pore water on the mechanical resistance offered by the soil should also be considered. An apparatus has been devised which permits the examination of the effects of the ambient pressure existing in a granular

material on the rate of root elongation. The apparatus may be regarded as a modified triaxial test cell in which a local, axial pressure is applied by an elongating root. Maize radicles were prevented from elongating through fine sands by an ambient pressure of less than one atmosphere. This result suggests that modest negative pressures or suctions in the pore water may have adverse mechanical effects on growth in certain soils.

The effect of a small axial load on the elongation of epicotyls of *Vicia faba* var. *minor* Beck. has been accurately measured. The shearing stresses established by the load changed the shape of the epicotyl without changing fresh weight or volume. An axial pressure of one atmosphere reduced the rate of elongation by one tenth. Although the maximum axial pressure which can be developed by the epicotyls (5 atm.) was first measured by Pfeffer in 1893, the measurements reported here appear to be the first that describe the effects of known axial loads on the rate of growth.

(g) *Permeability of Soils.*

(Dr. R. J. Millington and Dr. J. P. Quirk, Department of Agricultural Chemistry)

A comparison of measured and computed permeabilities was made for certain sediments using data on pore size distribution, formation factor, and measured permeability supplied by Dr. S. R. Faris of Socony Mobil Oil Co., Dallas, Texas. The method based on the matrix model previously described combined with the data on formation factor to produce very satisfactory agreement between computed and measured permeabilities.

CROPS

3. Crop and Pasture Ecology.

The chief interest in the ecological work of the Department is in plant competition, particularly with respect to competition for light.

(a) *Competition in Clovers.*

(Dr. J. N. Black)

The analysis of competition between strains of subterranean clover has been continued. It had previously been shown that when grown together without defoliation, strains with long petioles suppressed those with short petioles; and this was ascribed to modifications in the light environment of the more prostrate strains. A further experiment has been conducted in which the relative proportions of seed of two strains in the sowing mixture were varied. Even where the strain with long petioles was sown at a very low rate relative to the other, it rapidly became dominant.

The analysis has now been extended to competition between defoliated plants. Studies previously reported had been concerned only with swards growing without defoliation, and the next step was to examine competition between defoliated plants. In order that suitable strains might be chosen for experimental study, six commercial strains were grown in swards and their recovery from a single severe defoliation was measured. In general prostrate strains, e.g. Tallarook, recovered quickly, with a rapid increase in leaf numbers and a reduction in the average area per leaf, whereas tall strains, e.g. Yarloop, recovered slowly with some loss of plants from the sward. The Tallarook and Yarloop strains are therefore contrasted not only in growth habit and seed colour, but also in response to defoliation, and are thus suitable for further examination. Pure swards of these two strains and a mixture of equal numbers

of plants of each were sown in autumn and were grown until seed had been set. The swards were defoliated regularly, and were harvested at intervals between defoliations. It was found that plants of Tallarook remained in the mixed swards, whereas it is known that they are suppressed when the Yarloop component is allowed to grow unchecked. It was interesting to find that the late strain, Tallarook, produced more than the early strain only at the end of the growing season in November.

A second detailed study concerned the effects of height of defoliation on the two strains mentioned above. The treatments were (a) no defoliation, (b) defoliation at a height which removed the superior Yarloop canopy, and (c) defoliation at a height which removed both Yarloop and Tallarook canopies. Recovery from two successive defoliations at an interval of four weeks was measured and the results are in process of analysis.

A further experiment with subterranean clover concerned the growth of individual subterranean clover plants in a sward as affected by the time of emergence of each plant. The dates of emergence of 8,500 plants were known and their final dry weights determined. It is clear that a late emerging plant is at a severe disadvantage if surrounded by plants emerging only a few days earlier, and may contribute little to the total productivity of the sward.

A visiting Fulbright Fellow, Dr. W. A. Williams of the Agronomy Department, University of California at Davis, examined the effects of competition between three different species of clover employing methods developed in the Institute for the analysis of competition between strains of subterranean clover. Success in the mixture depended on the height at which the leaves were held, and this in turn depended on the species and on the size of seed.

(b) *Grass-Clover Competition.*

(Dr. W. R. Stern and Professor C. M. Donald)

A detailed analysis of grass-clover relationships in swards of varying nitrogen status showed that the suppression of clover by grass at high nitrogen status is due to four quantitative and measurable effects, namely (a) increased rates of nitrogen application give increased yields of grass, (b) increased yields of grass give higher leaf areas of grass disposed above the clover leaf canopy, (c) higher leaf areas of grass above the clover reduce the light intensity of the clover leaf canopy, and (d) the reduced light intensity causes a reduced growth of clover. Under conditions of heavy grass growth and consequent low light intensity at the clover canopy, the growth of clover not only becomes slow but eventually strongly negative, leading to a marked reduction both in the number and size of clover plants.

(c) *Leaf Area, Radiation and Growth.*

(Dr. W. R. Stern and Professor C. M. Donald)

A study has been made of the relationship of the growth rate of clover to its leaf area index and to the level of radiation. It was shown that the value of the optimum leaf area index of the sward increases as with increased level of radiation, and further that as the leaf area index increases, the level of radiation for maximum growth also increases. A schematic account has been published showing the relationship of these factors, including the incidence of negative growth rates at high leaf areas or at low levels of radiation. It is thought that these relationships are of general application in plant communities.

(d) *Leaf Growth and Senescence in Clover.*

(Dr. W. R. Stern)

Detailed studies were made of the initiation, development, expansion, senescence and death of individual leaves in swards of subterranean clover at densities of 4, 16 and 36 plants/dm.^{2} Leaves were labelled as they appeared on randomly selected plants, while frequent harvests (16 harvests in 160 days) provided an account of the lamina height, area, weight and the petiole length. The longevity of the leaf was about six weeks, and in that period lamina weight rose to a peak and then declined; a leaf showed no visual symptoms of senescence until it had lost 25 per cent. of its maximum weight. In general, growing leaves overtopped and shaded earlier leaves and caused them to decline in weight. However, there was also an ontogenetic component, so that leaves commonly fell from their maximum weight while still under optimum light conditions. These relationships were similar at each density, though the weight and leaf number per plant were much less at higher densities.

(e) *Competition in Cereals.*

(Mr. D. W. Puckridge, Mr. V. D. Wasserman and Professor C. M. Donald)

Competition between wheat plants sown at a wide range of densities is being studied with particular reference to competition for light. Although yield of grain is reduced at extremely high densities, the most striking result in 1961 was that the experimental crop produced comparable yields of dry matter and grain at sowing densities ranging from 35 to 875 plants per sq. metre. Work is continuing on the environmental factors and stage of growth governing tiller production and the survival of the ear primordium.

(f) *Competition between Wheat and Undersown Pasture Species.*

(Mr. K. Santhirasegaram and Dr. J. N. Black)

In 1960, wheat and annual pasture species were sown alone and in various combinations, using a range of planting patterns. Five harvests were taken at monthly intervals, commencing in August, and measurements of the light profile and soil moisture were made weekly. Pasture growth in the establishment year was significantly reduced where a wheat cover crop was used and seed production was also reduced. In 1961, it was found that the early production of these pastures was less than that of pastures originally sown without a cover crop, but the difference diminished later in the season. The 1960 experiment was followed in 1961 by studies of (a) the effects of sowing in a N : S direction as against E : W on the growth and yield of both cereal and undersown pasture plants, and (b) the position of the rows of pasture plants in relation to the wheat drills. Observations were made on the light microclimate and pattern of leaf development as well as on the yields of cereal and pasture.

(g) *Field Experiments on the Defoliation and Regrowth of Pasture Plants.*

(Mr. E. D. Carter and Mr. I. Whittaker)

During 1961 field experiments were begun on the artificial defoliation of subterranean clover var. Bacchus Marsh and on Wimmera ryegrass (*Lolium rigidum*, Gaud). The experiments were not grazed. One experiment on autumn defoliation is designed to assess whether lengthening the period between the opening rains and the first defoliation can substantially increase the availability of herbage during the more critical winter months. Four different intensities of

defoliation (unmown, mown to ½in., 1in., 1½in.) are also being compared. Experiments on spring defoliation are being carried out to determine how much herbage need be left to provide adequate regrowth for hay or silage making. Four intensities of defoliation (unmown, mown to 1in., 3in., 5in.), and two times of defoliation are being compared. The regrowth of stem and leaf and the yield of clover seed are being measured. The experiments should evaluate some of the factors involved in the complementary management practices of "deferred grazing" and fodder conservation.

(h) *Vernalisation and Growth in Lolium Species.*

(Mr. J. H. Silsbury)

The growth of vernalised and unvernalised plants of *Lolium perenne* L. and *L. rigidum* Gaud has been measured, with particular attention to tillering, heading, and the rate of dry matter production. Vernalisation increased the rate of dry matter production of *L. perenne* in the field and of *L. rigidum* grown in a controlled environment cabinet. The increase was associated with a higher rate of leaf appearance per tiller and a greater proportion of fertile tillers in the vernalised plants.

4. Botany, Plant Introduction and Testing.

(a) *Botany.*

(Mr. D. E. Symon)

Taxonomic investigations have been continued together with the supervision of the botanical service, the Herbarium, and the Arboretum. During 1960-61, 600 plants were identified and described on request. Important finds were *Avena ludoviciana,* a new Wild Oat, *Cyperus avenarius,* a weedy Sedge from Pt. Augusta, *Cyperus brevifolius,* Mullumbimby Couch, a weedy Sedge in suburban lawns, *Nothoscordum inodorum,* False Garlic, a weedy bulb from several suburban gardens, *Ornithogalum umbellatum,* Star of Bethlehem, now well established at Monarto South, *Homoglossum watsonium,* a further genus of South African *Iridaceae* now sparingly established near McLaren Flat. Several well-established aliens which appear to be spreading are *Pallenis spinosa* now occurring in the Tarlee district and *Limonium thoninii,* Winged Sea Lavender, now in the southern Flinders. Two seeds identified for the E. & W.S. Department from water filters at Mannum proved to be species of *Lactuca,* Wild Lettuce, and *Hypochaeris,* Cats Ear. These were of interest in view of the popular claim that many weeds are distributed by the Murray water. The two species above had not been implicated and those species usually claimed to have arrived in the water have not been found. Two species first recorded in South Australia in the 1930's were again found in the original localities, which suggests they are now established although still localised. The plants were *Echium vulgare,* Bugloss, from Clare, and *Euphorbia cyparissias,* Cypress Spurge, from an Adelaide suburb. An unusual record was of *Utricularia* spp. probably *U. flexuosa* from Wilpena. This had only been recorded in South Australia from Mt. Gambier in the last century.

About 2,900 sheets of new specimens were incorporated into the Herbarium which now contains 24,000 sheets. Specimens were made available on loan to taxonomists in the Herbaria at Melbourne, Sydney, Armidale, Perth and Adelaide. Specimens were exchanged with Herbaria in South Africa and California.

Tree planting in the Arboretum continued and the collections of *Eucalyptus*

and *Casuarina* were extended. In addition, a number of arborescent monocotyledons and succulents were established (*Aloe, Dracaena, Nolina, Yucca, Euphorbia, Cercus*). Seed and plant material was made available to the Botanic Garden, Housing Trust, Woods & Forests Department, and local Councils.

(b) *Introduced Perennial Grasses.*

Mr. J. H. Silsbury and Mr. J. A. Carpenter)

The evaluation of material introduced from the Mediterranean area has been continued, and seed of four contrasting ecotypes of cocksfoot (*Dactylis glomerata*) has been released to State Departments of Agriculture. Factors controlling growth during summer are being examined in a number of ecotypes of this species. Cultivars of *Lolium perenne* superior to "Clunes" or "Colac" in summer persistency and autumn regeneration are being further examined. In 1960-61 small plots were established from seed obtained in isolation from selected plants of six lines. Mortality in these swards over the exceptionally dry summer 1960-61 varied from 80 to 100 per cent. A further selection for drought resistance was made and about 20 plants of each line re-isolated for seed increase. A half pound of seed of each line was obtained and it is planned to use this for further sward testing and seed increase in 1962.

(c) *Introduced Grain Legumes.*

(Mr. J. H. Silsbury)

Variation in the yield of newly introduced pea cultivars has been measured in relation to the White Brunswick variety at the Waite Institute and country centres. Data on the yielding ability of peas, *Lathyrus cicera,* and *Lathyrus sativus* was obtained during 1960 and 1961, but no one cultivar or species proved consistently capable of producing higher yields of grain than White Brunswick. This work has not resulted in the production of a strong competitor for White Brunswick, but it is likely that C.P.I. 15247, a new white seeded pea, of equivalent quality, will be a valuable alternative to Dun or Collegian in the pea-growing areas of higher rainfall. A breeding programme designed to combine the high total yield of one cultivar with the high seed-setting ability of another has been commenced by the Plant Breeding Section.

5. Plant Breeding and Crop Genetics.

Breeding and genetic studies of cereals and perennial grasses have continued. The breeding of field peas was begun in 1960.

(a) *Cereals.*

(i) *Barley* (Dr. K. W. Finlay and Mr. D. H. B. Sparrow).

Further testing was undertaken at the Institute and at country centres to provide data for genotype—environment interaction studies with large numbers of varieties from the barley collection. A simple biometrical technique has been evolved enabling varieties to be classified according to their ability to adapt to a wide or narrow range of environments. It is now possible to recognise the type of varietal adaptation of early generation hybrids and to breed and select for this characteristic. Because of the extreme seasonal variability of factors such as rainfall in South Australia, these studies are providing valuable information on widely adapted potential parent varieties and their countries of origin.

Diallel and top-cross testing has been continued to measure general and specific combining ability of potential parent varieties for the breeding pro-

gramme. Results obtained at several locations for several years are being processed to indicate the usefulness of these techniques for prediction.

Barley varieties from Central Europe have been combining well with other barleys, and crosses were therefore made during 1961 with varieties recently obtained from Germany against a panel of five "tester" varieties whose performance under local conditions is already known. A set of 25 crosses was made during the winter, and the F_1 generations are being grown in a cooled glasshouse during the summer. Combining ability analyses will be performed on the bulk F_2 populations grown in 1962. It is intended to continue this technique for a number of years, testing a range of other varieties for combining ability and their potentiality as a source of improved varieties.

In 1960, F_2 generation populations of a number of crosses, selected on their performance in the combining ability trials of previous years, were harvested as single plants. In 1961 seed of 100 single plants from each cross was sown in single rows. A wide range of agronomic types was apparent, and an extensive appraisal was carried out. All the selections were harvested to provide an estimate of the yield potential of the crosses, and selected lines will be carried forward for further testing. Two crosses were outstanding.

Barley varieties have been shown to differ considerably in their ability to use nitrogen to produce additional grain. Although some varieties were able to respond to high levels of nitrogen, the local variety Prior proved to be inefficient. On some soils it showed a decrease in yield with added nitrogen.

Micro-malting equipment installed during the past two years was used throughout 1961 to malt samples from the 1960 barley trials. Samples of some 50 varieties were malted and the resultant malts are undergoing analysis. These malt analyses, together with an analysis of various grain characters, will provide the basis for a survey of the malting potentialities of varieties and single plant selections. Several of the varieties shown to have the best yield potential possess poor malting quality. Extensive quality testing is being undertaken with hybrids involving these varieties to assess their usefulness in a malting-barley improvement programme. Samples of hybrids and parent varieties from a 10 x 10 diallel experiment have also been malted and await analysis. These will provide a genetic appraisal of the malt characters.

(ii) *Wheat* (Dr. K. W. Finlay and Mr. K. W. Shepherd).

The testing of the wheat collection in country areas has continued. Several hundred of the more promising varieties have been assessed for agronomic and physiological characters in much more detail. There are now sufficient data available to enable genotype-environment interaction studies to be carried out on all 3000 varieties of the collection. Information gained about the country of origin of widely adapted varieties will be invaluable in designing a breeding programme.

An expanded crossing programme, involving the combination of "introduced" varieties with Australian wheats, has been initiated. This approach is being undertaken because of the reduced variability now available in the Australian gene-pool.

A study of the genetic control of flour quality in wheat has been begun. Three Australian varieties, with high, medium and low quality flour respectively have been selected for further study. Monosomic lines for each of the twenty-one different chromosomes present in these varieties are being produced. The first cross pollinations have been made to produce hybrids between the three

Australian varieties and monosomic lines of Chinese spring wheat. Backcrossing will be used to produce monosomic lines of the Australian varieties. These monosomic lines will be used in a substitution line breeding programme to obtain grain suitable for measuring the genetic contribution of each chromosome to flour quality. Data being obtained on this material by the Department of Agricultural Chemistry and the Australian Bread Research Institute will make it possible to study the inheritance of protein constitution of wheat flour and of flour quality.

(b) *Perennial Grasses*

(Mr. R. Knight)

Seventy-two families of *Dactylis glomerata* L. obtained by the hybridization of nine lines were grown at close spacing in 1959 and 1960. The plants were not defoliated. Samples of whole plants were frequently taken. Two- to three-fold inherited differences in plant weight were found between the families. The plants were sub-divided into roots, leaf bases, and leaves, and large inherited differences were also found in the weights and proportions of these parts. An attempt is being made to relate the inherited differences to the origin of the parents.

Dactylis strains from the Mediterranean become dormant in summer and have a high survival rate from year to year. Strains from Northern Europe remain green and suffer high mortality. One experiment has shown that hybrids survive almost as well as the Mediterranean parent, but nevertheless the hybrids are capable of producing new leaves after summer rains. The parent and hybrid plants have been clonally propagated, and in 1961 a further two trials were planted. Yields were estimated by defoliation at several times during the year, and a comparison was made between an irrigated and a dry-land experiment. These two experiments will be continued for several years.

(c) *Field Peas.*

(Dr. K. W. Finlay)

A 6 x 6 diallel test of five introduced and one local variety was conducted in 1960. The F_1 lines of the hybrids were grown in 1961. Flowering and maturity time, and yield of seed and dry matter are being determined. This programme is based on the data collected in the studies of grain legumes described under 4 (c).

(d) *Cytology.*

Extensive observations on chiasmata in *Dactylis* had been completed by Dr. K. Abele shortly before his death in a car accident in December, 1960. Further analysis of the excellent records left by Dr. Abele is being undertaken with the help of Drs. D. Hayman and P. Martin of the University of Adelaide, and Mr. K. Cellier of C.S.I.R.O., Division of Statistical Mathematics.

6. The Nutrition of Sheep in the Field.

(a) *Under-Nutrition during Pregnancy, Pre- and Post-Weaning Periods.*

(Mr. W. G. Allden and Mr. G. C. Everitt)

An experiment to examine the effects of severe under-nutrition during pregnancy on Merino ewe and lamb performance commenced in the Spring of 1961. A total of 75 experimental animals is being stocked at the rate of 11 ewes on 1·5 acres of a phalaris (*Phalaris tuberosa* (L.)) dominant pasture. One group of 11 ewes ("control") is receiving supplementary feed to maintain body

weight throughout gestation. Widely different degrees of weight loss in early pregnancy are being achieved in five other groups of ewes. Three of these groups will receive supplementary feed in the latter part of pregnancy. An objective estimate of changes in body composition occurring in the ewes, and later in the lambs, is being obtained with a skin/fat/muscle biopsy technique.

In a further experiment concentrate supplements varying in energy and protein content were fed during the last six weeks of pregnancy to maiden Merino ewes grazing the mature summer herbage of subterranean clover-annual grass pastures. The bodyweight loss in this period of the unsupplemented group (after correcting for the weight of the conceptus) was 7·4 lb., whereas at the highest level of supplementation nett bodyweight was maintained. There was no difference between treatment groups in terms of the birthweight of the lambs or rate of growth of lambs.

The earlier study of the relative effects on productivity of pre-weaning (birth to six months) and post-weaning (six to 12 months) nutrition in autumn dropped Merino lambs has been continued. The sheep are now 4½ years of age and the effect of a 16 lb. weight difference at weaning due to pre-weaning nutrition has been reduced to 6 lb. A weight difference of 22 lb. brought about in the second six months of life diminished rapidly and lost significance within a period of nine months. Similarly, the residual effect of pre-weaning under-nutrition on subsequent wool production has been of greater magnitude and duration than the effect of post-weaning under-nutrition. The study will continue for another 12 months.

(b) *The Utilization of Feed Nitrogen.*

(Mr. W. G. Allden)

The influence of feeding supplements varying in energy and protein content on the excretion of nitrogen by sheep grazing the mature herbage of sown pastures has been studied. Increasing the energy content of the supplement reduced nitrogen excretion, whereas an increase in protein resulted in higher levels of nitrogen excretion. These results provide quantitative data relating to the utilization of feed nitrogen under field conditions.

Agricultural Chemistry

This Department continues to investigate fundamental chemical and physical aspects of soil, plant and animal systems. The biochemical work has as its principal objective an understanding of the way in which the enzymes from the cell nucleus and cytoplasmic inclusions control cell development. Closely allied to this work is research on the chemical nature of plant viruses. Studies on the nature of proteins in the wheat grain are directed towards an understanding of flour quality for baking. The research on soils is concerned with the nature and properties of the surfaces occurring in soils, as well as transport mechanisms whereby water and nutrients are transferred to the growing plant. One objective of this work is to arrive at an appropriate physico-chemical model for the soil-plant system.

1. Chemistry of Cell Growth and Cell Division.

(a) *Purification and Properties of Nicotinamide Mononucleotide — Adenylyl Transferase.*

(Professor R. K. Morton, Dr. M. R. Atkinson and Mr. J. F. Jackson)

This enzyme has been isolated from the nuclei of pig liver and purified by adsorption on calcium phosphate, fractionation with ammonium sulphate and chromatography on diethylaminoethyl cellulose. The final product catalyses formation of 2-3 micromoles of nicotinamide adenine dinucleotide (coenzyme 1)/minute/milligram of protein when assayed in the presence of nicotinamide nucleotide, adenosine triphosphate and magnesium. Kinetic studies of the mechanism of dinucleotide coenzyme formation have been extended to other monophosphate-triphosphate pairs and it was found that dinucleotide formation took place when the nicotinamide part of the monophosphate was replaced by nicotinic acid, 3-acetylpyridine, pyridine 3-aldehyde and thionicotinamide but not by pyridine itself. When the adenine part of the adenosine triphosphate was replaced by hypoxanthine, guanine, 8-azaguanine and 6-mercaptopurine or the ribosyl part by 2-deoxyribose the corresponding nucleoside triphosphates could be converted into dinucleotides in the presence of the transferase. A number of undescribed coenzyme analogues were prepared in this way and some of their physical and biochemical properties have been studied. The "unnatural" triphosphates are effective inhibitors of natural nucleotide coenzyme formation, and there is some evidence that 6-mercaptopurine might exert its inhibition of cell division through competition of its riboside triphosphate with adenosine triphosphate in this and related reactions.

The requirement for cations during enzymatic dinucleotide formation has been studied. In addition to the known activation by magnesium and manganese it has been shown that nickel, cobalt and zinc ions will participate in the reaction. Preliminary experiments show that the activation by nickel is much more strongly suppressed by beryllium ion than is the activation by magnesium ion.

(b) *Synthesis of Analogues of Pyridine Nucleotides and of Related Compounds.*

(Professor R. K. Morton, Dr. M. R. Atkinson and Mr. R. Naylor)

A number of ribosides and phosphoribosides of pyridine derivatives have been prepared by the reaction of protected ribosyl halides with the pyridines, followed by removal of protecting groups and phosphorylation. Dowex-2 bicarbonate in methanol was found to be a convenient reagent for the removal of acyl protecting groups. This conventional synthesis of nucleotides gives a mixture of α and β anomers which is less suitable for biochemical studies than the pure β anomer. A new synthesis of pyridine nucleosides has been developed; glycosylamines react with dinitrophenyl pyridinium compounds, forming glycosyl pyridinium derivatives. Unprotected glycosylamines form unnatural pyranosides, but the desired ribofuranoside configuration can be obtained when 2,3,5-tribenzoylribosylamine is used in the reaction.

Attempts to prepare phosphonate analogues of phosphorylated metabolites are still hindered by the difficulty of hydrolysing protective ester groups from the phosphonates without damaging other sensitive groups in the molecules.

(c) *Pyridine Nucleotide Coenzymes in Animal Tissues.*

(Professor R. K. Morton, Dr. M. R. Atkinson and Mr. P. Caiger)

Reliable analyses of the oxidised and reduced forms of nicotinamide adenine dinucleotide and its phosphate in tissues are needed because of the wide involvement of these compounds in biological oxidation and their possible function in controlling cell growth and metabolism. Neutral, acid and alkaline extraction procedures have been combined with specific enzymatic assay methods for the

four compounds. In a series of experiments in collaboration with Mr. I. G. Jarrett and Mr. O. H. Filsell of the C.S.I.R.O. Division of Biochemistry these four coenzymes have been measured in the livers of rats, lambs and sheep of various ages. Highly significant relationships were found between coenzyme concentrations and stage of development. These experiments support earlier indications that high rates of cell division are associated with low concentrations of coenzymes; the experiments have also provided useful information for an assessment of the metabolic differences between ruminants and non-ruminants before and after weaning.

Formation of nicotinamide adenine dinucleotide and its phosphate from nicotinamide in slices of rat and chicken liver and in ascites tumour cells has been studied. No increase in coenzyme concentration could be shown in the presence of nicotinic acid. The relative importance of metabolic pathways involving nicotinamide nucleotide and nicotinic acid nucleotide is now being studied.

(d) *Synthesis of Pyridine Nucleotides in Plants.*

(Professor R. K. Morton, Dr. M. R. Atkinson and Professor C. V. Ramakrishnan (Rockefeller Travelling Fellow))

Pyridine nucleotide coenzyme formation in animal tissue has been studied extensively for some years, but no information was available on the formation of these coenzymes in plants. Unlike liver and yeast, wheat roots and artichoke tubers could not be shown to form nicotinamide adenine dinucleotide from nicotinamide nucleotide. However, the reaction sequence was shown:

(1) nicotinic acid + phosphoribosyl pyrophosphate $\xrightarrow{\text{(mitochondria)}}$ nicotinic acid nucleotide;

(2) nicotinic acid nucleotide + adenosine triphosphate $\xrightarrow{\text{(nuclei)}}$ nicotinic acid adenine dinucleotide;

(3) nicotinic acid adenine dinucleotide + glutamine + adenosine triphosphate $\xrightarrow{\text{(soluble fraction of cell)}}$ nicotinamide adenine dinucleotide.

Reaction (1) could not be shown in corn shoots, and the possibility that shoots depend on roots for a supply of ribosyl or phosphoribosylnicotinic acid must be considered.

Pure nicotinic acid nucleotide for this study was prepared from nicotinamide nucleotide and nitrous anhydride. Nicotinic acid adenine dinucleotide was prepared from nicotinic acid nucleotide and adenosine triphosphate in the presence of adenylyl transferase from pig liver nuclei and pyrophosphatase from yeast.

Intact nuclei were prepared (in experiments carried out with Dr. J. B. Hanson (Fulbright Travelling Fellow)) by blending artichoke or wheat root in solutions of suitable viscosity and electrolyte concentration.

(e) *Enzymatic Properties of Isolated Nuclei and Inhibition of Nicotinamide Adenine Dinucleotide Formation.*

(Professor R. K. Morton, Dr. M. R. Atkinson and Miss Joan Hallett)

Nuclei of liver and tumour cells have been compared with the purified transferase from liver nuclei. Rates of nicotinamide adenine dinucleotide formation and apparent Michaelis constants for nicotinamide nucleotide and adenosine

triphosphate were studied. Interaction of nicotinamide nucleotide is similar with enzyme in solution or bound to nuclei, but a much higher concentration of adenosine triphosphate is needed to give maximum rates with nuclei than with soluble enzyme. This may be due to the high adenosine triphosphatase activity of nuclei. Extrapolation of rates to infinite substrate concentrations gives a more reliable measure of enzyme activity in whole nuclei and confirms Morton and Branster's earlier observation that tumour nuclei are relatively ineffective in catalysing nicotinamide adenine dinucleotide formation.

Adenosine diphosphate was found to replace the triphosphate for dinucleotide synthesis with nuclei, but the nuclei contained enough adenylate kinase to explain this observation. No evidence could be found for oxidative phosphorylation in liver nuclei.

A number of organic ligands, reagents for -SH groups, alkylating agents and derivatives of pyridine and pyrophosphate have been studied as inhibitors of nicotinamide adenine dinucleotide formation with the transferase from liver nuclei.

(f) *Heliotrine Poisoning and Nicotinamide Nucleotide Coenzyme Metabolism in Liver.*

(Professor R. K. Morton, Dr. M. R. Atkinson and Mr. A. W. Murray)

Preliminary experiments have been carried out on the protection afforded by nicotinamide against the stock poison heliotrine. The effect of these chemicals, alone or together, on the concentrations of nicotinamide nucleotide coenzymes in mouse liver has been studied. No inhibition of nicotinamide nucleotide adenylyl transferase could be shown. At doses causing death within 48 hours heliotrine caused marked changes in the cytoplasm of the liver cell, as revealed by electron microscopy; vesicles and large electron-dense bodies were frequently observed.

An improved general analysis of tissue nucleotides by spectrophotometry after purification on ion-change paper has been developed.

Preparations of mitochondria from mouse and rat liver were shown to catalyse synthesis of nicotinamide nucleotide from nicotinamide and phosphoribosyl pyrophosphate. The possibility that this is the first step in coenzyme synthesis from nicotinamide is being examined.

(g) *The Deoxyribonucleic Acid from Type I Cytochrome* b_2.

(Professor R. K. Morton and Dr. M. D. Montague)

The polynucleotide from Type I cytochrome b_2 was freed of protein by treatment with ammonium sulphate and chromatographed in a sodium chloride gradient on "ecteola"-cellulose (an anion exchanger). Material which emerged from the column as a single peak was treated with phosphomonoesterase to remove terminal phosphates and then with phosphodiesterase to break up the polynucleotide chain. The only nucleosides liberated were deoxyguanosine and deoxycytosine, which are considered to be derived from the terminal nucleotides of two polynucleotide chains.

2. Studies on Enzymes which Catalyse Biological Oxidation.

(a) *The Structure of Cytochrome* b_2 (*Lactate Dehydrogenase*) *of Bakers' Yeast.*

(Professor R. K. Morton, Miss Kathryn Shepley, Mr. J. McD. Armstrong and Dr. J. H. Coates (Department of Physical and Inorganic Chemistry))

From the crystalline Type I cytochrome b_2, which contains polydeoxyribonucleotide, flavin and haem in association with the enzyme protein, a number of derivatives have been obtained. These include a crystalline flavohaemoprotein (Type II) with no polynucleotide, a haemoprotein Type IV with no flavin or polynucleotide, a flavoprotein (Type V) with no haem or polynucleotide and a protein (Type VI) without flavin, haem or polynucleotide. A modified haemoprotein (Type III) was also obtained; the absorption spectrum and chemical properties of this derivative indicated the existence of an attachment between enzyme and haem similar to that in cytochrome *c*. The reduced haemoprotein was a substrate of cytochrome oxidase.

Types 1 and 2 cytochrome b_2 were further examined in the ultracentrifuge and by electrophoresis in solution; in some experiments the flavin was released from the enzyme with urea before examination. None of these studies showed more than one protein component in the enzyme preparations.

(b) *Studies on Nucleotides and Oxidative Metabolism.*

(Dr. M. R. Atkinson and Dr. M. Dixon, F.R.S. (Department of Biochemistry, University of Cambridge))

Diaphorase (reduced nicotinamide adenine dinucleotide ($NADH_2$) : lipoamide oxidoreductase) from pig heart muscle has been shown to catalyse electron transfer from the nucleotide coenzyme to oxygen. With an oxygen electrode and manometrically it was shown that diaphorase also catalyses electron transfer from dihydrolipoamide to oxygen. The reaction is more rapid in the presence of nicotinamide adenine dinucleotide, the rate being doubled at a coenzyme concentration of $4 \times 10^{-7} M$.

Preparations of $NADH_2$: lipoamide oxidoreductase and $NADH_2$: cytochrome *c* oxidoreductase from heart muscle were separated, by electrophoresis in starch gels, into a number of fractions with enzymatic activity. The former enzyme has been degraded to its constituent peptides with trypsin and the mixture has been fractionated by electrophoresis. The nature of these multiple forms of enzymes is being studied. A number of constituents of heart mitochondria have been separated by electrophoresis in starch gels containing urea.

The kinetics of electron transfer from succinate to a number of oxidants has been studied with extracts from heart-muscle particles. Measurement of the half-lives of aerobic inactivation of catalytic intermediates between $NADH_2$ or succinate and cytochrome *c*-cytochrome oxidase indicates the presence of more than one labile catalyst.

Pyridine has been studied as an inhibitor of electron transfer from ethanol to nicotinamide adenine dinucleotide in the presence of dehydrogenases from yeast and liver. The results are consistent with models in which one pyridine may compete with ethanol and two with the coenzyme at their binding sites. The possibility that both alcohol and coenzyme are bound to a zinc atom in the enzyme is being studied.

(c) *Effects of Lipoic Acid on Oxidative Phosphorylation.*

(Mr. D. Bottrill, Dr. A. A. Millerd and Professor R. K. Morton)

Studies have been continued on the components of the respiratory chain of animal and plant mitochondria. The nature and locus of the inhibition exerted by lipoic acid on oxidative phosphorylation have been further examined. It became apparent that a photolysis product of lipoic acid, rather than lipoic

acid, is the inhibitor. The chemical characteristics of the active compound are being considered.

(d) *The Effect of Fungal Infection on the Respiration of Barley Leaves.*

(Dr. A. M. Millerd and Dr. K. J. Scott)

An increased rate of respiration of plant cells characteristically accompanies their infection by a wide range of pathogens. This respiratory response is of interest to biochemists investigating mechanisms of respiratory control and to plant pathologists for its significance in overall disease symptoms. A comparison has been made of the utilisation of energy produced by the respiration of non-infected barley leaves and by barley leaves infected with *Erysiphe graminis* var. *hordei* (powdery mildew). Correlations have been made of respiratory rates with dry weights, amounts of protein, ribonucleic acid and deoxyribonucleic acid. Such quantitative comparisons can be used to indicate the extent to which electron transport is coupled with adenosine triphosphate synthesis. Results obtained indicate that portion of the increased respiration of the infected tissue can be explained by increased synthesis.

3. The Metabolism of Oxalis Pes-Caprae.

(Dr. A. A. Millerd, Professor R. K. Morton and Mr. J. R. Wells)

Oxalis pes-caprae (soursob), an annual weed prevalent in arable land in the Adelaide plains, accumulates large amounts of oxalic acid in leaves and petioles. In investigations into the mechanism of synthesis of oxalic acid by this plant, a number of compounds have been considered as precursors. These compounds, labelled with ^{14}C, have been injected into shoots and after incubation for one hour, the pattern of ^{14}C distribution determined.

From qualitative and quantitative studies with ^{14}C-labelled glucose, glyoxylate, glycollate, serine, glycine and glycerate, fructose and bicarbonate, some steps in the synthetic pathway have become apparent. Glycollate and glyoxylate have been shown to be the immediate precursors of oxalate. In addition, cell-free preparations from *Oxalis* have been shown to form oxalate from glycollate and glyoxylate. Purification of this system is proceeding and it will be used for the study of compounds which will specifically inhibit oxalic acid production.

4. Chemical Studies of Mature and Developing Wheat Grain.

(a) *Wheat Flour Proteins.*

(Dr. J. S. D. Graham, Professor R. K. Morton and Dr. D. H. Simmonds)

Proteins have been extracted from wheat flour with water-saturated butanol, 0·01 M sodium pyrophosphate (pH 7·0), 0·05 N acetic acid (pH 3·5) and 0·1 N sodium hydroxide. Chromatography of the pyrophosphate soluble proteins on DEAE-cellulose yielded eight fractions and separations of the acetic acid soluble proteins on CM-cellulose yielded 10 fractions. These investigations have been carried out on flour of different baking qualities and certain correlations could be made both in the proportion of the proteins extracted and in the chromatographic elution patterns.

The proteins present in the pyrophosphate and acetic acid extracts have been examined by starch gel electrophoresis. Separations by starch gel electrophoresis yielded 20 components in the pyrophosphate extract and electrophoresis of the fractions separated on DEAE-cellulose showed that a considerable number of the components were common to a number of the fractions. Of the 13 components

found in the acetic acid extract at least eight were identical with those separated from the pyrophosphate extract.

(b) *Proteins of Developing Wheat Endosperm.*

(Dr. J. S. D. Graham and Professor R. K. Morton)

The changes in protein composition of wheat endosperm during development has been examined for the three wheat varieties "Gabo", "Insignia" and "Dural". In all three varieties there is rapid protein synthesis during development and the major part of this increase occurs in the acetic acid soluble (or storage) proteins. Chromatographic elution patterns of the pyrophosphate and acetic acid soluble proteins remained approximately constant for each variety throughout development.

^{35}S-carrier free sulphate has been used to study protein synthesis in developing wheat endosperm. ^{35}S-sulphate, taken up by tillers harvested at a stage during rapid protein synthesis, was rapidly incorporated into the endosperm protein. The distribution of radioactivity showed an initial incorporation into the pyrophosphate soluble proteins with negligible radioactivity in the acetic acid-soluble proteins. With increasing periods of exposure to the ^{35}S-sulphate there was a steady increase in the amount of ^{35}S incorporated into the acetic acid soluble proteins and a decline in the amount of radioactivity present in the pyrophosphate soluble proteins. Radioautographs have been obtained of the starch gel electrophoresis patterns of the ^{35}S-labelled protein extracts. The use of ^{35}S- rather than ^{14}C-labelled compounds for studies in protein synthesis has the advantage that all the labelled compounds formed are extracted during the protein extraction procedure. In contrast endosperm labelled with ^{14}C-acetate yielded 60 per cent. of the incorporated radioactivity in the starch function.

(c) *Studies of the Subcellular Components of Developing Wheat Endosperm.*

(Mr. J. K. Raison, Mr. B. A. Palk, Professor R. K. Morton and Dr. J. S. D. Graham)

Investigations of the changes in chemical composition of wheat endosperm during development have been accompanied by investigations of the morphological changes using the electron microscope. Work is now in progress to isolate some of the subcellular components and to establish their chemical composition.

The electron dense granules, identifiable in thin sections of intact immature endosperm, have been isolated from homogenates of endosperm by differential centrifugation as a reasonably homogenous fraction. The electron dense granules are believed to be the storage protein of the grain. Since it is now possible to prepare bulk fractions of these granules identification of the proteins in the granule will be made by starch gel electrophoresis and the components will be compared with protein extracts obtained from whole endosperm tissue.

Studies have been made of the enzymes in the supernatant solution remaining after centrifugation at 105,000 x g., and preliminary results indicate that the amino acid activating enzymes are present. Using the ribonucleoprotein particles and the 105,000 x g. supernatant components attempts will be made to develop a system for enzymic studies of protein synthesis.

(d) *Chemical Changes in the Developing Wheat Grain.*

(Professor R. K. Morton and Mr. A. C. Jennings)

This study showed that during development the sugars and amino acids translocated to the endosperm and testa-pericarp are immediately utilised for

energy production and synthesis of starch and protein and other constituents. The results indicated that the metabolic pathways shown to occur in other biological systems may also occur in the developing wheat grain.

The ratio of the amount of each protein fraction present to the amount of ribonucleic acid present during development was determined. The ratio of pyrophosphate-buffer-soluble protein to ribonucleic acid increased at first then remained constant over the later stages of development, whereas the ratio of the other protein fractions to ribonucleic acid increased continually throughout development.

The results showed that the developing wheat grain passes through three different periods of physiological development, which are (1) a period in which cell division and synthesis of cytoplasmic components predominates, (2) a period in which synthesis of starch and storage protein predominates, and (3) a period in which the desiccation of the grain is the dominant feature.

This study also indicated the way in which the composition of the mature grain is influenced by the nature of the external environment during each of these physiological periods of development.

(e) *The Amino Acids of Developing Wheat Grain.*

(Professor R. K. Morton and Mr. A. C. Jennings)

Information is required of the rate of incorporation of the individual amino acids into both the endosperm and testa-pericarp portions of the wheat grain throughout development. The results show that the relative rate of incorporation of each amino acid differs so that the relative amount of each amino acid present changes continually throughout development. Glutamic acid is incorporated at a very much greater rate than any other amino acid.

5. Endocrine Studies.

(a) *The Intracellular Location of the Enzyme Responding to Adrenalin.*

(Dr. I. R. Falconer, Professor R. K. Morton and Mr. N. S. Scott)

One of the distinctive biochemical effects of adrenalin is the release of glucose from the liver into the blood. This appears to be caused by the activation of liver phosphorylase, which converts glycogen into glucose 1-phosphate. The activation of phosphorylase is probably due to the adrenaline stimulated formation of cyclic 3′5′-adenosine monophosphate from adenosine triphosphate. The properties of the enzyme forming cyclic 3′5′-adenosine monophosphate are being investigated in liver cell fractions and methods have been developed to separate and indentify the small amounts of the cyclic phosphate produced. The intracellular location of the cyclising enzyme is also under investigation.

(b) *The Influence of the Thyroid Gland on Reproductive processes in the Ewe.*

(Dr. I. R. Falconer)

This investigation of the influence of the thyroid on reproduction in the ewe developed from observations of variations in thyroid activity during pregnancy and possibly during the menstrual cycle of women. In women pathological changes in thyroid activity lead to reduced fertility, primarily through amenorrhea but partly through abortion. Thus the thyroid varies in activity during reproduction in women, and also strongly affects reproduction.

The first phase of this investigation was to measure the variation in activity of the thyroid during growth, the oestrous cycle, pregnancy and lactation in the ewe. This phase is now largely complete, and has led to the discovery of

a cyclical change in thyroid activity in the ewe, associated with oestrus. No significant changes were found during pregnancy, but during lactation a small increase in thyroid activity was observed.

To establish the importance of the thyroid during reproduction in the ewe, the straightforward approach of surgically thyroidectomising one-half of a ewe flock was used. This flock was then put with a teaser vasectomised ram until some 60 oestrous cycles had been recorded. A normal ram was put in with the ewes, and the conception rate and subsequent pregnancy observed.

This type of fundamental physiological investigation into the hormonal control of reproduction is hoped to lead to a better understanding of how fertility may be improved in the Merino ewe.

(c) *The Metabolism of Radioactive ^{131}Iodine in the Lactating Ewe and Suckling Lamb.*

(Dr. I. R. Falconer)

The thyroid iodide uptake is greatly depressed during lactation, due to competition for circulating iodide by the mammary glands. Iodide secreted in the milk is absorbed into the lamb's bloodstream, and a proportion taken into the thyroid. The present work is concerned with the kinetics of the uptake of ^{131}I into the thyroid, into the milk, and into the urine and faeces of the ewe. The radioactive milk is bottle fed to lambs and the uptake of ^{131}I into the lambs' thyroids measured. The results of this study should offer information on the distribution of an ion in a system where four separate biological processes are acting competitively.

(d) *Development of Surgical Techniques for a Study of Thyroid Function in the Ewe.*

(Dr. I. R. Falconer)

Aseptic surgical procedures are being developed for the externalisation of thyroid glands, thereby enabling short-time changes in thyroid activity to be measured.

6. Physico-Chemical Studies of Clays and Soils.

(a) *Structural Status of Clay Systems.*

(Dr. L. A. G. Aylmore and Dr. J. P. Quirk)

Studies on the micropore (< 100Å) size distribution were undertaken to give background information for the interpretation of the swelling of clay materials. Homoionic clays in equilibrium with $P/Po = 0{\cdot}96$ were compressed into cores at a pressure of 1,200 atmospheres. After drying complete adsorption-desorption isotherms for liquid nitrogen were obtained at $-195°$ C.

The pore size distribution of the clay cores were obtained by applying the Kelvin equation to the desorption isotherms. A cyclindrical meniscus was assumed and allowance was made for a decrease in liquid content due to the thinning of the absorbed film in pores from which the evaporation of capillary condensate had previously taken place.

The kaolinites examined gave isotherms typical of coarsely crystalline materials and exhibited a plate explanation of > 100Å. The other materials gave well-defined pore size (crystal separation) distributions. The shapes of the isotherms indicate the presence of wedge and slit-shaped pores with a dominant separation between crystals of 30-60 Å.

A clay matrix is regarded as being made up of small regions of crystals in almost parallel and interleaved arrangements. Such an arrangement has been

referred to as a domain and the domains form a turbulent array within the clay mass. Further information on the nature of a domain is given by an electron micrograph of a shadowed replica of the fracture surface of a clay core. The domain concept has proved valuable in interpreting the behaviour of clay water systems.

(b) *The Mechanism of Clay Swelling and Clay Water Relationships.*

(Dr. L. A. G. Aylmore, Dr. A. M. Posner and Dr. J. P. Quirk)

The swelling behaviour of Na^+ and Ca^{++} clay cores has been analysed in terms of the domain model and the specific surface area of the clay.

Measurements of the effect of electrolyte concentration and hydrostatic suction on the swelling of Na^+ and Ca^{++} clay cores indicate:

1. That diffuse double layer theory describes the swelling of Na^+ clay systems in a semi-quantitative way.
2. That diffuse double layer theory cannot be used to describe the swelling of Ca^{++} clay systems.
3. That many kaolinites show anomalous behaviour in that the swelling of the Na^+ clay is no greater than that for the Ca^{++} clay.

The magnitude of the film thickness, apparently developed in solutions as concentrated as 4 M $CaCl_2$, where the conditions of ideal solution required by diffuse double layer theory is certainly not fulfilled, indicates that the relaxation of structural strains within the clay matrix on lubrication with solutions is an important cause of swelling. These strains arise from the distortion of crystals in packing during the drying process. The large hysteresis in the water content-energy relationship for these systems supports this interpretation.

An important requirement in interpreting the behaviour of clay water systems is to separate water simply enmeshed (held by surface tension forces) from water held at the clay solution interface by physico-chemical forces. To achieve this end and to allow more rigorous thermodynamic treatment of the results an apparatus has been constructed to measure the swelling pressure developed with virtually no volume change under a variety of conditions.

(c) *Distribution of Chloride Ions at Clay-Solution Interface.*

(Mr. D. G. Edwards, Dr. A. M. Posner and Dr. J. P. Quirk)

The diffuse double layer theory has been used to examine anion distribution adjacent to and between charged plates. For Na^+ montmorillonite the results are satisfactorily explained by the plates being separated by a distance of 4/K. The results for Ca^{2+}-montmorillonite are explained as being due to a Donnan equilibrium for the internal crystal surfaces and diffuse double layers on the external crystal surfaces.

In these experiments ^{36}Cl determined by liquid scintillation counting is being used to measure chloride ion distributions. Current experiments are concerned with the effect of increasing double layer interaction caused by applying pressure.

It has been previously mentioned that clay materials swell considerably in solutions as concentrated as 4 M $CaCl_2$. To investigate this effect adsorption isotherms (25° C.) have been determined for sodium, potassium and calcium chlorides and calcium nitrate on the corresponding cation montmorillonite. The isotherms have been obtained over a wide range of electrolyte concentration extending up to the solubility limit. Isotherms for the sodium clay have also been obtained at 5° and 60° C.

The form of the isotherms does not follow that to be expected from a simple Donnan exclusion equilibrium. The first part of the isotherm is linear over a considerable range of concentration and then there is a sudden transition to a horizontal part in which the negative adsorption is constant. Decreases in the basal spacing of the clay which occur with increasing electrolyte concentration give rise to the sudden levelling of the negative adsorption.

A tentative reason for the swelling behaviour of the clay may be given as the preferential adsorption of water over salt solution. There is apparently a barrier which prevents the full penetration of salt to the surface of the clay even in very strong electrolyte solutions. This barrier appears to be associated with the sharp levelling of the isotherms and the theoretical reason for its existence is being sought.

(d) *Adsorption of Organic Compounds by Soils and Clays.*

(Mr. J. R. Burford, Dr. D. J. Greenland, Mr. R. H. Laby, Dr. J. P. Quirk and Mr. B. K. G. Theng)

Physical properties of surface soils are largely dependent on the effects of organic polymers on the aggregation of the inorganic soil colloids. A range of polyvinyl alcohols has been used to determine the effect of molecular size and shape and limited chemical substitution in the chain on the adsorption of the polymer, and on the changes in the properties of the substrate following adsorption onto clay minerals, aluminium oxides, silica and soil clays. It has been found that very considerable differences occur both with variations in the specific properties of the organic polymer, and with variations in the substrate. Some materials are relatively inert in relation to polymer adsorption, while others adsorb as much as 1 g. per g. of clay. It has been shown that the adsorption usually follows an H-type (Langmuir) isotherm, although in some instances maxima have been observed in the isotherms, and the adsorption may differ with the more completely hydrolysed polyvinyl alcohols. The adsorption is irreversible. The clay-polyvinyl alcohol complexes formed have been further studied by X-ray diffraction analyses, infra-red spectroscopy and electron microscopy.

The adsorption by montmorillonite and illite of the peptide series glycine, glycyl glycine, glycyl glycyl glycine and glycyl glycyl glycyl glycine has been studied since it was thought that this might provide valuable information relating to the retention by soil clays of amino-acids and amino-acid containing molecules such as occur in soil organic matter.

Adsorption isotherms of glycine and its di-, tri-, and tetrapeptides from aqueous solution onto sodium, calcium and hydrogen montmorillonite and sodium and calcium illite have been determined at 0 and 25° C. The complexes formed have been examined by X-ray diffraction. For the adsorption on calcium montmorillonite, linear isotherms were obtained, and by treating the adsorption as a constant partition of solute between solution and the Stern layer of the adsorbent, free energies, enthalpies and entropies of physical adsorption were determined. These results showed that the relative affinity of the clay for these compounds was a linear function of molecular weight while both the heat and entropy of adsorption were least for glycyl glycine. Experiments in water and calcium chloride solutions showed that ion-dipole interactions played a significant rôle in determining the adsorption energy.

In addition, twelve further amino-acids have been studied in some detail to determine specific effects of functional groups in the adsorption process.

Adsorption isotherms have been obtained for ethyl, butyl, octyl, dodecyl and cetyl pyridinium bromides on sodium and calcium montmorillonites. It has been found that, for an alkyl chain of eight carbon atoms or less, adsorption does not exceed the exchange capacity of the clay, but for the larger molecules adsorption proceeds much beyond this.

The adsorption of cetyl pyridinium bromide (CPB) shows considerable promise as a method for measuring the surface areas of soil clays. CPB adsorption isotherms are of the Langmuir type and when the area occupied by a CPB molecule is taken to be 27Å^2 the surface area of the clay calculated from the Langmuir monolayer agrees with that obtained by nitrogen adsorption, provided that no expanding-lattice material is present.

The area of 27Å^2 per molecule corresponds to a double layer of molecules on the clay surfaces, the second layer being held by van der Waals attraction between the hydrocarbon chains which are perpendicular to the clay surface. The adsorption of CPB appears to have special promise as a method of measuring the internal and external crystal surface area and hence in combination with low temperature nitrogen adsorption measurements should be useful in detecting interstratification in clays.

The adsorption of nitrogen, CPB and various complex cobalt ions onto soil aggregates before and after removal of the soil organic matter has been used to determine how soil organic matter affects adsorption by the clay. It has been found that the organic matter has a very large surface area to CPB, but a much smaller area to nitrogen. This suggests a structure comparable to that of cellulose fibres, which swell in water thereby making internal adsorption sites accessible. Complete removal of organic matter by strong hydrogen peroxide treatment leads to "edge exfoliation" of the clay lattice and renders interpretation of the results in terms of surface coverage of the clay by the natural organic compounds difficult.

(e) *Mechanism of Soil Aggregation.*

(Mr. T. L. Deshpande, Dr. D. J. Greenland, Mr. G. Lindstrom (Fulbright), Dr. J. P. Quirk and Mr. B. K. G. Theng)

The rôle of organic matter and iron oxides in modifying the physical behaviour of soils is being investigated with respect to the effect these materials have on water stable aggregation and on the swelling behaviour of clays.

Natural soil aggregates have been treated with dilute sodium periodate followed by sodium borate solution. This treatment leads to the breakdown of polysaccharides and polyuronides into non-polymeric components, so that soil aggregates cemented by these materials tend to disperse. It has been shown that Red Brown Earth aggregates in continuously cultivated soils and those under short-term pastures are very sensitive to the treatment. Under older pastures the periodate sensitive materials play some part in the cementation of aggregates but other organic materials are also involved. Aggregates from Solonized Brown Soils are in general somewhat less sensitive to periodate treatment and Rendzinas are usually unaffected by the treatment.

Soil samples containing various amounts of iron oxides and organic matter were collected in the vicinity of Adelaide and were also obtained from Lismore in N.S.W. and Katherine in the Northern Territory. In many soils relatively little effect of free iron oxides has been found. An interesting feature of the results is that a number of samples show limited swelling when Na^+-saturated even when iron oxide and organic matter are removed. The hypothesis that

aluminium oxides may be important in stabilizing soil microaggregates by cementing clay particles is therefore being examined.

Polyvinylalcohol and some quaternary ammonium salts have been adsorbed onto two clay mineral types, a montmorillonite and an illite. Montmorillonite intercalates molecules and hence the relative position and orientation of these molecules in interlamellar regions can be followed by X-ray diffraction techniques. Illite, on the other hand, is a non-expanding lattice mineral and hence adsorption takes place on the external crystal surface only. Modification of the interparticle forces due to the adsorption of these compounds is being studied.

7. Studies on Soil Phosphorus in Relation to Plant Nutrition.

(a) *Adsorption of Phosphate by Kaolinite.*

(Mr. D. G. Lewis, Mr. D. Muljadi, Dr. A. M. Posner and Dr. J. P. Quirk)

Earlier work on the adsorption of phosphate by clay minerals is being completed and more detailed studies on the adsorption of this anion by kaolinite are in progress. In connection with phosphate adsorption and other adsorption studies detailed work has been carried out on the release of aluminium and silicon from clays when treated with dilute acid in the presence of salt solutions. Important information on the nature of the soil surfaces and reactivity of edge faces of clay crystals is being obtained in this way.

The adsorption isotherm of phosphate on K^+-kaolinite obeyed the Langmuir equation up to a concentration of 5×10^{-3}M. The value of V_m, that is the amount of H_2PO_4' adsorbed forming a monolayer, was 3 me. per 100 g. The maximum value of chloride adsorption was approximately 3 me. per 100 g. This result and studies of the residual chloride adsorption after adsorption of H_2PO_4' have led to the conclusion that H_2PO_4' is adsorbed onto positively charged reactive aluminium situated on the edge face of the crystal. Very marked hysteresis was noted between adsorption and desorption isotherms. Details of this hysteresis have been investigated and its relation to the decreased availability of phosphate to plants has been considered.

The mechanism of phosphate retention by kaolinite has been studied by adsorption of this ion onto K^+-kaolinite. This work is preliminary to an investigation on the mechanism and kinetics of desorption.

An adsorption equation which described the phosphate adsorption by K^+-kaolinite has been derived. The initial part of the isotherm is due to a reaction between H_2PO_4' and the available aluminium on the exchange sites. pH is the principal factor affecting this part of the reaction. The second part of the reaction is distinct and is governed by H_2PO_4' concentration as well as pH. The site for this latter reaction is the aluminium on the edge face of the crystal.

(b) *Dissolution and Hydrolysis of Calcium Phosphate.*

(Mr. D. G. Lewis)

Reagent grade monocalcium phosphate was shaken with distilled water in various solid to liquid ratios and the resultant solution analysed for phosphorus and calcium and the residual solid examined by X-ray crystallography. The results confirm earlier observations of Stephenson. The effect of calcium sulphate on the solubility and hydrolysis has also been determined by mixing reagent grade calcium phosphate and calcium sulphate in appropriate amounts to correspond to the theoretical composition of superphosphate.

The concentration of phosphate was unaffected while the calcium concentration was increased by an amount corresponding to the solubility of gypsum.

The nature of the precipitate formed when the pH of these calcium phosphate solutions was raised has also been briefly investigated.

(c) *Diffusion of Ions in Moist Soil.*

(Mr. D. G. Lewis and Dr. J. P. Quirk)

Previous work has been concerned with the rate at which phosphate is accumulated by a wheat plant under a variety of soil phosphate conditions. To interpret this flux and hence to arrive at an appropriate model for the plant root soil system diffusion studies were carried out.

The apparent diffusion coefficients of Na^+, K^+, Cl' and H_2PO_4' have been calculated for soils at pore saturation by measuring the changes in concentration with time when a sample containing the ion under consideration is brought into intimate contact with a similar sample without any added ion. The values obtained for K^+, Na^+, and Cl' in the soil system show satisfactory agreement with previous literature data.

For chloride the apparent diffusion coefficient in soil systems was found to be approximately 30 per cent. of the value for aqueous solutions, with variation in chloride addition from 1 to 10 me. per 100 g. having very little effect on the value (1×10^{-6} cm.^{2}/sec.).

However, for the phosphate ion, which is held by the soil particles much more avidly than most other ions, extremely low values have been found for diffusion rates even at very high levels of applied phosphate (approximately 10^{-9} cm.^{2}/sec. after addition of 2000 parts of phosphorus per million of soil). These values are of a similar order to the diffusion coefficients of Jenny and co-workers suggesting that movement over surfaces may be an important mechanism in the transport of soil phosphate to the root prior to uptake by the plant.

(d) *Residual Phosphorus in Red-Brown Earth Soils.*

(Prof. L. T. Kurtz (Fulbright) and Dr. J. P. Quirk)

Over a number of years dressings of superphosphate have been applied to cropped and pasture lands. Adsorption isotherms have been obtained for H_2PO_4' on Red Brown Earth soils which have received large dressings of superphosphate. The results indicate that the adsorption capacity of the clay is not affected by these previous dressings. It therefore appears that crystalline phosphates represent the form of the residual phosphate.

8. Soil Organic Matter and Nitrogen.

(a) *Organic Matter Levels in Soils and Cropping History.*

(Dr. D. J. Greenland)

The rate of breakdown and build-up of soil organic matter in a Red Brown Earth has been analysed using samples taken from the C1 Rotation Trial in 1925 and 1961. Considered with other published data the results indicate that the rate of breakdown is much greater in the first year(s) of cultivation than subsequently. It has been shown that different lengths of pasture alternating with cropping periods lead to different equilibrium levels of soil organic matter (and soil nitrogen). An equation has been developed to describe the soil nitrogen level in terms of cropping history.

A study is also being made of the organic matter in soils which is not combined with the heavier inorganic colloids. This macro-organic matter has been separated from the denser soil material by a benzene-bromoform solution of s.g. 2·0. Macro-organic matter has a large surface area and hence may play an important rôle in some soil processes.

(b) *The Surface Chemical Properties of Soil Organic Matter.*

(Dr. A. M. Posner)

The value of surface chemical techniques in the characterisation of soil organic matter is assessed. Preliminary experiments on humic acids extracted from a continuous wheat fallow rotation and pasture have established that insoluble surface films cannot be obtained at the air/water interface over a wide range of pH values, salt concentration and salt types. A film can, however, be obtained at the oil/water interface when the water contains 35 per cent. ammonium sulphate.

The above behaviour suggests that either the humic acid does not spread properly or because of its colloidal character and the presence of a large number of hydrophilic groups, the humic acid is carried through the surface into the bulk.

The effect of methylating these hydrophilic groups is to be examined.

9. Physical Studies on Soils.

(a) *Studies of Permeability, Ionic Diffusion and Gaseous Diffusion in Porous Media.*

(Dr. R. J. Millington (Dept. of Agronomy) and Dr. J. P. Quirk)

The transfer of constituents such as water and nutrient ions from the soil to the plant is a fundamental process in agriculture. It is therefore essential that the basic features of mass transport and diffusive flow should be understood with respect to appropriate models of the plant root soil system.

A model has been developed which satisfactorily describes the flow water and diffusion of gas in saturated and partially saturated media. Consideration has been given to the way in which the ideal model will have to be modified to allow for changes in the probability of continuity which arises from pore aggregation, i.e. non-random distribution of pore size classes.

It has been shown that the formation factor which is widely used in oil-industry flow studies should be especially useful in defining porous materials. The formation factor is the ratio of the resistivity of a porous material saturated with a conducting electrolyte to the resistivity of the electrolyte. Surface conductivity of clay materials would not be a serious objection to the application of this measurement since a molar calcium chloride solution could be used without appreciably affecting the natural structure.

10. Chemistry of Plant Viruses.

(a) *Preparation of Pure Tomato Spotted Wilt Virus.*

(Dr. R. J. Best)

The preparation of pure samples of the virus of tomato spotted wilt (TSWV) presents difficulties because the virus is readily inactivated by oxidising systems in the plant sap and because of its general lability. A medium has now been developed in which the infectivity of the virus and its physical integrity can be maintained during the stresses of high speed centrifugation. By the subsequent application of density gradient centrifugation in sucrose the bulk

of the virus has been isolated in a light-scattering band of high specific infectivity and of sufficiently high purity to warrant certain tests. The light-scattering band obtained at an average depth of 30 mm. in the gradient tubes has been re-cycled, with the result that a high quality product has been obtained.

The ultraviolet absorption curves of the material, when corrected for the extensive light scattering, conform to the type characteristic of nucleoproteins.

Dry weight determinations revealed that the yield of pure virus at the maximum production rate of the Spinco SW 25 head varied between 1 and 3 milligrams per week.

An attempt was made to increase the rate of production by using larger quantities of plant homogenate in a high speed angle centrifuge capable of handling larger volumes. The trials showed that density gradient separations can be made successfully in an angle rotor but so far losses associated with this method are too great.

(b) *Physical Properties of Tomato Spotted Wilt Virus.*

(Dr. R. J. Best)

When the sedimentation velocity of samples of TSW Virus, as prepared above, was determined in an analytical ultracentrifuge the Schlieren diagram revealed only one component and conformed to that of a nucleoprotein shape. The sedimentation constant calculated from the data was 439 S.

(c) *Studies on the Morphology of TSW Virus with the Electron Microscope.*

(Dr. R. J. Best and Mr. B. A. Palk)

Grids sprayed with solutions of the virus from the first density gradient cycle and containing either phosphotungstate or uranyl acetate reveal particles of oval or rectangular shape whose longer dimension slightly exceeds 80 $m\mu$ and shorter one is somewhat less. Preparations from the re-cycled density gradient when sprayed onto grids show particles in various stages of disruption. The particles appear to be easily flattened and distorted (giving larger measurements than those recorded above) and inner structures are revealed. The interpretation of these photographs is proceeding.

Pellets of the virus obtained by centrifuging preparations made by density gradient techniques have been embedded in methacrylate resin after being fixed in osmium tetroxide. Sections, when counter-stained with uranium acetate or lead hydroxide, show the virus as relatively uniform, dark, oval bodies. The dimensions of these bodies were smaller than those observed on sprayed grids. The interpretation of this and other data is proceeding.

(d) *The Genetics of Tomato Spotted Wilt Virus.*

(Dr. R. J. Best)

(i) As part of the preparations for the next phase in the investigation of the genetic recombinants reported in previous reports, samples of the parent strains and of the progency strains of the virus have been purified biologically by the single lesion at limit dilution techniques developed in this laboratory, and these have been preserved for further use by storage at low temperature as noted below.

(ii) The disadvantage of the short *in vitro* life of this virus has now been overcome by the discovery that virus infected tissues retain their infectivity for at least six years when stored at $-69°$ C. in a box cooled by solid CO_2.

(iii) Because our work was the first to demonstrate a process of hybridization between strains of a plant virus it was particularly important to exclude

the possibility of normal mutation as the cause of the variants obtained. To test this possibility comparison has been made between the recombination rate and the normal mutation rate of the more unstable parent strain under controlled conditions.

In each of two experiments a leaf which had received a mixed inoculum (strains A and E) was homogenised soon after the appearance of symptoms and, after suitable dilution, was inoculated ("plated out") onto a number of leaves of indicator plants to type and analyse the strains present. When the new strains (variants) were expressed as a percentage of the total number of lesions obtained, the new strains were found to constitute 10 per cent. of the total in one experiment, and 20 per cent. in the other.

The frequency with which either of the parent strains (A and E) mutated naturally was at least two orders of magnitude lower than this.

In a specially designed experiment we obtained a mutation rate of 1 in 505 for parent strain E, although the virus must have gone through several cycles of replication. This compares with rates of 1 in 10 and 1 in 5 in the mixedly infected plants and shows that the latter process is quite different from a normal mutation.

(e) *Chemical Composition of Pure TSW Virus.*

(Dr. R. J. Best)

Preliminary work has shown that the phosphorus and ribose contents of our early preparations were consistent with a nucleic acid content of 5 per cent. for the whole virus, but the percentage of nitrogen does not seem to be high enough for this. Preparations made by density gradient centrifugation have, therefore, been re-cycled, as described above, and we are at present engaged in building up a stock of pure virus to enable adequate chemical studies to proceed.

(f) *Other Investigations.*

(Dr. R. J. Best)

Infectious Phenol Extract of TSW Virus Infected Leaves.

Using the phenol extraction method of Engler and Schramm, an infectious inoculum was prepared from the aqueous phase, which contains nucleic acid but no protein. The resulting infectious agent was re-transmitted to indicator plants, but the reaction was different in character and milder than that of the original whole virus. These differences indicate that changes have taken place in the genetic constitution of the virus as a result of the treatment.

Relative Concentration of TSW Virus in Various Parts of Plants.

On continuing the tests on the relative concentration of the virus in various hosts and parts of them it was found that strain E of the virus occurred in the primary lesions of tobacco, systemically invaded leaves of tobacco, primary lesions of *Nicotiana glutinosa*, systemically invaded leaves and roots of *N. glutinosa* at the following standard infectivities: 210, 570, 4,040, 1,610, 1,030 respectively.

General Tests of the Effect of Various Systems on TSW Virus in Solution.

During the course of developing suitable media and testing of specific ideas, the following observations were made. Pyrophosphate and acetate buffers are as good as phosphate but "tris" buffer inactivates the virus. The presence

of Mg at 10^{-3} molar concentration had no significant effect on infectivity, but EDTA in concentrations around 10^{-4} molar in the inoculums increased the number of lesions by up to 46 per cent., whereas at concentrations of 10^{-2}M it depressed it.

11. Studies of Analytical Procedures.

(a) *The Determination of Nitrogen.*

(Mr. A. C. Jennings)

Conditions for the quantitative recovery of micro-amounts of ammonia by steam distillation were established. A steam distillation unit suitable for the recovery of ammonia in macro, semimicro and micro amounts was developed. The macro-Kjeldhal digestion procedure was satisfactorily modified to give a greater output of samples with considerable economies in the amount of reagents used. A procedure was developed by which the determination of low levels of nitrate in soil can now be conveniently carried out by steam distillation in the presence of Devarda's alloy and borate buffer.

The procedures previously used for the determination of the nitrogen content of cereal grain samples have been modified further to allow larger numbers of samples to be analysed each day. The availability of suitable capped plastic centrifuge tubes has allowed some of the manipulations previously necessary to be eliminated.

(b) *Mechanisms of the Biuret Reaction.*

(Mr. A. C. Jennings)

Further studies of the biuret reaction indicated the presence of large numbers of copper to oxygen as well as copper to nitrogen bonds in the complex formed between copper and protein in alkaline conditions. Because of the heterogeneous nature of the individual chelates formed, it apears unlikely that the biuret method for protein determination can be modified in any way to give more accurate results than those obtainable in its present form.

(c) *The Determination of Available Phosphorus in Soil.*

(Mr. A. C. Jennings and Mr. J. K. Powrie (Agronomy Department))

A method suitable for the rapid determination of the available phosphorus content of soils was developed. In this procedure, portions of soil are treated with an acid molybdate reagent and immediately extracted with isobutanol. The isobutanol extract is diluted with acidified alcohol and stannous chloride added to reduce the phosphomolybdate complex. There was a high degree of correlation between extracted phosphorus and the total phosphorus content of the soils studied. The solubility of several phosphate-containing minerals was examined using this extraction procedure.

Plant Physiology

Research has been continued on the following topics: growth-regulators, growth studies on cereals, carbohydrate metabolism, nutrition, flower and fruit development in horticultural crops. Several projects have involved collaboration with either, in the field, agronomists, or in the laboratory, biochemists; in others, collaborative work has been desirable but impracticable and we have conducted the necessary field work or physico-chemical studies ourselves.

1. Growth Regulators

(a) *The Responses of Sour-Sob to Growth-Regulators*

In the previous report, emphasis was placed on the fact that sour-sob (*Oxalis pes-caprae*) showed a high resistance to weedicides of the growth-regulator type. Nevertheless, following the application of 2,4-D labelled with radioactive carbon, radioactivity was detected throughout the entire plant. The development of the scintillation counting technique (see (f) below) has allowed the metabolic fate of applied 2,4-D to be followed in more detail, and results from this method have confirmed the previous conclusion that the resistance of sour-sob to 2,4-D is due, at least in part, to the inability of this plant to metabolise the 2,4-D molecule. Further, it has been established that both uptake through leaves and translocation to underground parts are restricted and it thus appears that resistance in this plant operates at three levels, namely, uptake, translocation and metabolism. To penetrate these three barriers to resistance clearly presents a formidable task.

(b) *Root Contraction in Sour-Sob.*

The dependence of contraction in the tuberous root of sour-sob on the aerial parts of the plant has been mentioned before. By various manipulations of the conducting tissues of the stem, Dr. N. G. Marinos has established the phloem as the pathway for the contracting stimulus. Whatever the nature of this stimulus may ultimately turn out to be, it is clear that loss of water from the tuberous roots via the transpiration stream is not the primary mechanism of root contraction.

Autoradiographic studies (see prior report) using ^{45}Ca indicated that calcium accumulated preferentially in zones of collapsing cells. More recent studies on the uptake of radioactive calcium by segments from contracting and non-contracting portions of tuberous roots have confirmed the finding that a higher uptake occurs in contracted regions. This preferential uptake does not appear to be associated with an "active" process and the most likely explanation is that in the contracted portions the Apparent Free Space of the tissue is greater due to the greater volume of cell wall in relation to total volume. Thus it is unlikely that accumulation of calcium has much to do with regulating the phenomenon.

(c) *Dormancy.*

This project began with an investigation of the mechanism of action of the inhibitor-beta complex while Dr. Marinos was on Study Leave collaborating with Professor T. Hemberg of the University of Stockholm. In Adelaide the study has been continued using the potato tuber although it is hoped to use bulbs from weeds in subsequent investigations. The opinion is widely held that natural dormancy is controlled by the balance of growth-promoting and growth-inhibiting substances, and to determine whether similar changes occurred during artificially induced dormancy potato tubers (variety *Sebago*) were treated with naphthaleneacetic acid. Although minor qualitative and quantitative differences were observed in the constitution of the inhibitor-beta complex of treated and non-treated tubers, most evidence leads to the conclusion that the suppression of bud growth after naphthaleneacetic acid treatment is due to the accumulation of supra-optimal levels of auxin (native indoleacetic acid already present plus naphthaleneacetic acid taken up during treatment). Thus native and artificially induced dormancy seem to be basically different in their underlying mechanisms.

Mr. B. K. Taylor, under Dr. Marinos' supervision, investigated dormancy in bulbs of Cape Tulip collected from both one- and two-leaved species. The amount of inhibitor-beta complex increased in various organs of the plants as the season progressed, although no general trend in the growth-promoting group was apparent. A study of the anatomy and physiology of the small cormils produced by the two-leaved species indicated that cormil dormancy is due to physical factors rather than to changing growth inhibiting substances.

(d) *Assay Techniques for Gibberellic Acid.*

This work has had as its objective the development of a simpler and more sensitive assay procedure than those available in the past. The idea came from Dr. L. G. Paleg's investigations on the release of reducing sugars from barley endosperm induced by gibberellic acid, and this worker, together with Dr. B. G. Coombe and Mr. P. B. Nicholls, has developed the technique to the stage where minute quantities of gibberellins present in shoot apices can be easily detected. To examine the selectivity of the endosperm response to changes in the chemical structure of the gibberellic acid molecule, seven active and one inactive (by other assays) gibberellins were tested. On the basis of their activity in the endosperm test the eight compounds could be separated into four groups; one compound previously thought inactive demonstrated medium activity in this assay, while two other gibberellins showed such a low activity as to point to contamination as the source of the observed response.

(e) *Interrelationships Between Growth Regulators.*

Dr. L. G. Paleg and Dr. D. Aspinall have measured responses induced by gibberellic acid and indoleacetic acid, applied either separately or together, on the growth and flowering of carrots. Stem elongation and flowering followed treatment with gibberellic acid and these responses were inhibited in the presence of indoleacetic acid. However, the latter hormone produced no measurable effects on either growth or flowering when applied alone.

(f) *Scintillation Counting Technique.*

Although scintillation counting techniques have been available for more than a decade, they have not been widely used in biological laboratories. There are many potential advantages for biological work, but there are also difficulties. The nature of the solvent, its concentration and volume, the nature of the scintillator and its volume all exert a critical influence on counting efficiency and in particular spurious counts introduced by alkalis at low normalities should be mentioned. Notwithstanding these difficulties, Miss Fay Chapman, working with Dr. Marinos, has now defined conditions which, when strictly pursued, allow estimations to be made on growth-regulators isolated from plant tissue.

2. Growth Studies on Cereals.

(a) *Responses to Drought.*

The installation of lysimeters (5ft. x 3ft. x 4ft.) has made possible a comparison of the following treatments in large volumes of soil: control, no water stress; water stress to anthesis; water stress during and after anthesis. Dr. D. Aspinall reports that the total grain yield was halved by late drought but unaffected by pre-flowering water stress in experiments during 1960. In 1961, the soil was changed from a clay loam to a light sandy loam, and, although yield was still reduced, the effects of water stress at anthesis were less severe. This difference probably arises because of a greater ability of plants to extract water from deeper levels in light sandy loams than in clay loams.

Investigations on the water relationships of grains during a period of stress have indicated an effect, at even moderate soil moisture tensions, on both grain moisture content and its ability to absorb water subsequently. Therefore, the conclusion is drawn that moisture stress reduces yield by a direct influence on the metabolism of the developing grains rather than indirectly through effects on the rest of the plant.

Grain dormancy was greatly increased by early water stress, although unaffected by a later stress, in the growth cycle of the 1959-60 season. Dormancy thus induced gradually declined with time and had disappeared eight months after harvest. This finding was confirmed in the 1960-61 growing season although the depth of grain dormancy produced was much less than in the previous season.

Mr. P. B. Nicholls conducted droughting experiments in pots with two barley varieties and obtained many results comparable with those just mentioned from work in lysimeters. He found that tiller and leaf production were retarded by early water stress although yield was not much affected. Grain yield and grain number were most significantly lowered following stresses during differentiation of the floral organs and after anthesis.

While on Study Leave at the University of Nottingham, U.K., Dr. L. H. May prepared, in collaboration with Professor F. L. Milthorpe, a review of the literature on the drought responses of crop plants. This is to be published early in 1962.

(b) *Tillering in Barley.*

The formation of side-branches, or tillers, in the barley plant depends on many factors although there is little doubt that the supply of mineral nutrients is a major controlling influence.

Tillering is also influenced by the development of grains on the ear and the interaction between this factor and mineral nutrient supply has been explored in two barley varieties; a high tillering variety (Piroline) and a low tillering one (CI3576). In Piroline, there was little control attributable to the ears, and grains had not apparently competed significantly with dormant tiller buds for mineral nutrients. In CI3576, however, there was strong competition for nutrients between developing grains and the dormant tiller buds. From these results Dr. Aspinall concludes that one of the differences between low and high tillering varieties is the comparative competitive abilities of tiller buds and stem apices for mineral nutrients.

Data collected by Dr. Aspinall and Dr. Paleg indicate that rate of tillering is also influenced by the total amount of light energy received, since either increasing the intensity at a fixed photoperiod or increasing the photoperiod at a fixed intensity increases the rate of tillering.

(c) *Flowering in Barley.*

Two varieties of barley (Prior "A" and CI5611) were grown at different daylengths (8, 16, 24 hr.photoperiods). The shorter photoperiods increased the number of primordia formed, the number of leaves below the first floret, and the time taken for floral development. An interesting correlation was noted between the cessation of primordia formation and the appearance of stamen initials on the most advanced floret. This relationship was unaltered by environmental changes. Mr. P. B. Nicholls infers from this observation that two processes, namely, rate of primordia initiation and rate of primordia development, determine the number of potential florets on the barley inflorescence.

Further information has come from microscopic examination of the inflorescence periodically throughout its development. The inflorescence increased in length solely by cell division at the terminal meristem as long as new primordia were being initiated. However, after primordia initiation had ceased the terminal meristem degenerated and new meristems became active at each node of the inflorescence.

(d) *Light Effects on Apical Development.*

Drs. Aspinall and Paleg have studied the influence of light quality, quantity and duration on several happenings at the apex of the barley plant. They have observed that in fluorescent light the rate of primordium initiation is constant with time and that one factor which alters this rate is light intensity. Moreover, whereas at low intensities (about 1500 foot candles) daylength is without apparent effect on the rate of primordium formation, at higher light intensities (about 3000 foot candles) the rate of primordium production is greater at long than at short photoperiods. When fluorescent light of low intensity is supplemented with incandescent light, however, there is a marked response to daylength at the lower levels of illumination (1500 foot candles) since at long photoperiods (16 hours) the rate of primordium production is greatly increased when as little as 10 foot candles of incandescent light are used as supplement. These results lead to the conclusion that some component of the spectrum is present at a very low level in fluorescent light and that a threshold level of this particular wavelength has to be exceeded before rates of primordium formation can be increased. To explore this possibility further, equipment for measuring light energy in narrow regions of the spectrum is being assembled.

Four varieties of barley (Prior, Noyep, CI3576 and CI5611) were planted in the field at three distances from a 500 watt incandescent floodlight giving light intensities at the plant's leaves ranging from 20 foot candles to below one foot candle. Plants were illuminated for two hours in the middle of the night. Illumination began four weeks after seed was sown and at this stage the apices of the two early varieties (Noyep and CI3576) were floral. Nothwithstanding all four varieties responded to night illumination by advanced stem elongation and date of anthesis, especially the late flowering variety (CI5611) in which the date of anthesis was advanced by about three weeks.

3. Carbohydrate Metabolism.

(a) *Responses of Barley Endosperm to Gibberellic Acid.*

During the germination of cereal grain carbohydrates in the endosperm are transformed and moved into the developing shoot. But the release of reducing sugars by the barley endosperm can be induced in the absence of the embryo when gibberellic acid is added. Dr. Paleg has examined this system in great detail during the past few years and many results have been published. Most recently he has noticed that the mobilization process in the endosperm can be inhibited, not only by removing embryos, but also by damaging them with X-rays. The application of gibberellic acid to seeds with damaged embryos overcomes the inhibition of carbohydrate mobilization as it does in seeds from which embryos have been removed. Moreover, intact normal grain also respond to gibberellic acid by showing more rapid mobilization of carbohydrates.

(b) *Carbon Fixation in the Cereal Ear.*

In a preceding report, work by Dr. M. S. Buttrose and Dr. L. H. May was presented showing that alternative techniques gave different estimates of the

contribution of ear photosynthesis to grain yield on barley. It was stated further that this contribution can be assumed to stand at its maximum value when determined by the competition technique. This method has been used again with the aim of assessing the importance of the wheat ear as a contributor to grain yield throughout the period from anthesis to maturity. In the wheat variety *Gabo* each floret increases its contribution to grain yield with time, and this increase parallels the increase in grain growth rate so that the proportion of substrate entering a grain, which comes from floret photosynthesis, remains approximately constant throughout development. The observed increase in rate of photosynthesis is probably due to an increase in the photosynthetic surface area, as the swelling grain forces the floret tissues further apart.

(c) *Starch Granule Synthesis.*

Studies of starch granule formation in barley endosperm carried out by Drs. May and Buttrose brought to light interrelationships between starch granules and the endosperm as a whole (see earlier reports) which required more detailed examination for their proper interpretation. After a period of training under Professor Frey-Wyssling in Switzerland, Dr. Buttrose has returned to these studies using wheat endosperm and the electron microscope. He has shown that granules are initiated in proplastids and that these grow in size until at least three weeks after anthesis. Starch granule development in wheat endosperm is very similar, then, to that in barley.

After acid pre-treatment, starch granules show a regular pattern of shells when examined in the electron microscope. In potato starch, shells are present in granules from plants grown under either continuous light or day-night alternations. In cereal starch, shell structure is observed only in granules from plants grown under day-night alternations. Aspects of this paradox such as the difference in alternating light intensities necessary to induce shell formation in cereals are receiving further attention.

In the belief that other environmental factors may influence starch granule structure, wheat plants have been grown under conditions of deficiency of one of the following elements: N, P, K, Ca, Mg. Preliminary observations suggest that differences in fine structure of the plastids do in fact occur where certain elements are in short supply.

In conjunction with these microscopic studies, Dr. Buttrose plans to measure certain physico-chemical properties of the same starches to determine whether morphology and rheology are related. For this purpose simple methods for measuring gelatinization, viscosity and rate of solubilization are being developed. One promising result that has already been obtained is that wheat starch granules produced in constant environment (that is, without shell structure) are more resistant to mineral acids than normal granules. It follows that structure and properties of granules are related, at least in this one instance.

4. Nutrition.

(a) *Nutritional Studies on Potatoes.*

During the period under review little work has been done on this problem.

(b) *The Influence of Mineral Deficiencies on Cell Ultrastructure.*

Dr. N. G. Marinos has as his aim in this work collecting information about the effects of mineral deficiency on the structure of individual units within a cell. For technical reasons the preliminary investigations have been confined to shoot apices taken from barley plants grown in a medium totally deficient with

respect to either one major or one trace nutrient. The picture revealed by the electron microscope of calcium-deficient plants is one of a profound effect on the structure of various membranes within a cell, in that these rapidly become disorganized. Cell wall changes have also been noted but these occur much later in the development of deficiency symptoms.

5. Flower and Fruit Development.

(a) *Apples.*

(i) Field Observations. A general characteristic of apples is that a heavy crop one year will be followed by a light one the next. Under local conditions, the relationship discovered elsewhere between leaf area of the whole tree and crop load in the following season has been confirmed in general terms. However, in detail, there are differences.

Mr. G. R. Edwards applied copper sulphate to "off-crop" trees of two varieties on a commercial scale and made comparisons between 1, 2 and 4 per cent. sprays applied during the first, second and third weeks of November, 1960. The trees were unpruned, small and lacking in vigour with a history of marked biennial bearing. The spray had much more severe effects on Statesman, where leaf abscission was rapid and regrowth extensive than on Jonathan where little leaf abscission occurred and regrowth was slight. Flowering and fruiting records are still being collected in the 1961-62 season and indications are that a practical control method might result. But two serious disadvantages of this method of crop regulation are apparent. Firstly, copper sulphate blemishes fruit severely; secondly, fruit clustering with its attendant problems occurs. For these reasons some of the newer compounds developed oversea for cotton defoliation are being applied in a small-scale test during the 1961-62 season.

To establish in quantitative terms the effect of leaf removal on locally grown varieties under our environmental conditions seven levels of leaf removal were imposed by hand on each of three varieties at three levels of vigour. Defoliation of spurs of Jonathan to nil and one leaf per spur reduced flowering from about 80 per cent. to 9 per cent. and 40 per cent. respectively. With Statesman, however, complete defoliation still resulted in 65 per cent. flowering and defoliation to one leaf 70 per cent. These levels are more severe than those found necessary by overseas workers, especially in the variety Jonathan; defoliation to two leaves is their threshold level, but this was inadequate to significantly reduce flowering under local conditions. Further hand defoliation experiments are in progress to examine time of treatment and the effect of ringing the experimental branch unit.

During the 1960-61 growth cycle, about 30 chemical compounds, including growth-regulators, amino acids, purine and pyrimidine analogues, were injected into otherwise untreated "on-crop", "off-crop", and defoliated "off-crop" branches of trees of three varieties. It is disappointing, although perhaps not surprising, to have to record that the only responses observed were an elongation in spurs injected with gibberellin and an increase in the numbers of adventitious buds in "off-crop", defoliated branches treated with kinetin. No significant differences were observed in flower initiation as a result of any of these treatments.

(ii) Observations in Controlled Environments. Following reports of the influence of photoperiod and red-far red wavelengths on flower initiation and leaf growth in many plants, Mr. Edwards began an investigation of the responses of apples to light treatments. Initially, treatments were imposed on

branches of trees growing in the field. Experience with these treatments, as well as other investigations, has led to the conclusion, however, that parts of trees cannot be used as experimental units for this work. For this reason, experiments are now being conducted in controlled environment rooms using plants either on dwarfing rootstocks or in root restricting containers. In one experiment, three light regimes were compared: fluorescent light, 14 hours; fluorescent light plus incandescent supplement, 14 hours; fluorescent plus incandescent light followed by two hours of low intensity red light. The variety Jonathan was used, and trees were three months from grafting, trained to two branches, and pruned to ⅓ their length at the beginning of the experiment. After two months the total leaf area of new growth, expressed as a percentage of the original leaf area was 44 per cent., 97 per cent. and 60 per cent. for the three light treatments respectively. Thus incandescent light increased markedly the area of leaves, an effect which was offset by low intensity red light.

(b) *Vines.*

As foreshadowed in the last report, Dr. B. G. Coombe has extended his studies on changes occurring during the development of the grape berry; studies which may for convenience be divided into two phases.

(i) Fruit Setting and the First Growth Cycle of Grapes. The practice of cincturing has been used for a long time to increase fruit set of currants, but the reason for this response is still unknown; it could be explained in terms of either food supply or hormone supply. To characterize the response further, measurements are being made of the rate at which the cincturing response occurs and the effect of cincturing on responses to applied hormones.

Set in seeded varieties of grapes is proportional to leaf number per branch, provided that complications due to immature leaves and shoot tips are taken into account. Although the nature of the setting process in seedless grapes is different, there is a similar need for mature leaves to attain maximum set. The smallest berry (currant) has been found to have the least leaf requirement.

An enlargement of grapes follows the application of growth substances and in this connection gibberellic acid (GA) enlarges currant berries more than the auxin parachlorophenoxyacetic acid (PCPA). It has been found, however, that together, these compounds act synergistically, a finding which could be of practical importance in lowering the cost of hormone induced enlargement (G.A. is by far the more expensive).

(ii) The Second Growth Cycle. The hypothesis has been proposed that the change from the hard, green state to the soft, variously coloured one is caused by a passive water movement following an active uptake of sugars into the berry. To test this idea, berries have been enclosed in plastic cages before the beginning of the second growth cycle to restrict their further development. A comparative series of berries has been enclosed in larger, non-restrictive cages. Measurements are in progress to compare sugar content, weight and skin colour of berries in the two series.

The active movement of sugar into grape berries during the second growth cycle seems, from field observations, to cease at about the same time each year, irrespective of seasonal conditions. This observation suggests that the climatic factor controlling sugar movement is length of day. To test this deduction, sultana vines have been illuminated so as to extend the daylength and also to break the night period. Red light has had no effect, but white, incandescent

light appears to increase the levels of sugar by 2-3 per cent. This finding must be regarded at present as tentative, but should it be confirmed, many implications will follow.

The mechanism responsible for sugar movement is being examined by measuring sugar levels following the application of several growth substances and in addition, by measuring enzyme changes in whole berries, peduncles and pedicels.

(c) *Stone Fruit.*

A year ago preliminary studies on changes in growth rate, size, auxin content and cell division were made on almonds. Fruit growth followed a sigmoid curve and, although size increase could be ascribed mainly to elongation, cell division was observed as late as 2-3 weeks after bloom and could be correlated with changes in gross auxin content. More recently Mr. D. I. Jackson has applied the techniques developed for almond to peach, but the data have still to be collated.

Entomology

1. Advisory Services

During the period under review, advisory services for the State Departments of Agriculture and Woods and Forests have been maintained. Assistance has also been provided for other governmental and semi-governmental bodies, as well as for the general public.

A new pest of stonefruits and almonds, the carob moth, *Ectomyelois ceratoniae* Zell., was recorded for the first time in South Australia. In the past, damage done by this species has been confused with codling moth damage.

The celery fly, *Melanagromyza apii* Hering, was first recorded in South Australia in 1960.

The larvae of a small, apparently-native moth, *Capua* sp., were found boring in celery. This is the first record of the species doing such damage in Australia.

2. Research

Most of the activity of the Department is directed towards the study of fundamental aspects of insect life since it is on such knowledge that rational methods of control must ultimately be based. During the past two years attention has been given to the following investigations.

(1) Insect Ecology

(a) *Codling moth,* Cydia pomonella (*L.*)

(Dr. D. A. Maelzer)

An attempt is being made to construct a life table for codling moth. Three independent methods of sampling are being used to estimate mortality at different stages of the life-cycle.

Information on adult activity, behaviour and flight range is being obtained by the release and capture of marked moths.

(b) *The Woolly Bear,* Ardices glatignyi *Le Guil.*

(Dr. D. A. Maelzer)

A wide range of colour patterns in both the caterpillar and the adult exists. A study has commenced on the possibility that this species is polymorphic.

(c) *The Lucerne-Pod Borer,* Etiella behrii [Zell.].

(Mr. D. J. Taylor)

Further studies on the ecology and biology of this species have been made. The part played by native legumes in maintaining the species has been elucidated. All its later generations develop within lucerne pods. The first spring generation of larvae, however, appears before lucerne has begun flowering; the larvae complete their development inside the fruits of a range of native and other introduced annual legumes, and it is from these larvae that the females, which oviposit on lucerne pods, develop.

A varying proportion of the larvae is parasitized by members of the Hymenoptera. This proportion changes from year to year, and efforts are being made to determine the factors which control the size of the parasite populations.

(d) *The Hellula Moth,* Hellula *spp.*

(Mr. A. G. Basson)

Investigation has shown that what has hitherto been regarded in South Australia as *Hellula undalis* (F.) is, in fact, a complex of *Hellula* species, of which *undalis* may or may not be one. The taxonomy of the complex is being investigated as a preliminary step in the study of the ecologies of its members.

It is hoped to construct life-tables for all stages and to discover the stage in which mortality is greatest. Particular attention is being given to the effects of food, water, and temperature on the longevity and fecundity of adults.

When the species have been sorted out, it may be possible to associate these with the variety of habitats, and the wide range of larval food plants. It may be that forms inhabiting arid environments are specifically different from those living in more favourable areas.

(2) Insect Physiology and Behaviour

(a) *Studies on Wing Polymorphism in Aphids.*

(Dr. B. Johnson)

Wing polymorphism in aphids is influenced by various factors. Among these are temperature, photo-period, parentage, nutrition, parasitism, ant-attendance, and crowding. The latter factor has been analysed in some detail, and it has been shown that the threshold of response to stimulation by other aphids is influenced by the other factors, and that the principal stimuli involved are tactile. When the threshold is sufficiently low, the crowding response may be induced by artificially stimulating the receptors.

(b) *Physiological Control of Wing-Polymorphism in Aphids.*

(Dr. B. Johnson)

The physiological mechanism whereby the parent aphid influences the form of its embryos is being studied. It has been shown that the embryos naturally develop as presumptive alates, and require a positive stimulus to be directed into the apterous course of development. When pre-natal diversion occurs, the embryo is apparently stimulated just before birth. Injuries to parts of the central nervous system of the parent can produce the stimulus, and attempts are being made to determine whether a humoral agent is involved.

(c) *Influence of Sulphanilamide on Aphids.*

(Dr. B. Johnson)

Aphids fed on, or injected with, dilute solutions of sulphanilamide suffer high mortality. Immature forms die during moulting. While adults are apparently unaffected, they produce embryos which desiccate as they are being born. Cuticles of newly-moulted, treated aphids are readily permeable to water, and it is suggested that sulphanilamide may be interfering with lipid metabolism. This possibility is being investigated.

(d) *Toxins Produced by Aphid Midgut.*

(Dr. B. Johnson)

When a short length of midgut from one aphid is implanted in another, the latter dies. Implantation of other tissues has no such effect. An attempt is being made to determine the nature of the toxin involved. It may have affinities with a pharmacologically-active substance recently reported from cockroach gut.

(e) *Feeding Mechanisms of the Hemiptera.*

(Dr. P. W. Miles)

According to their mode of feeding, the Hemiptera may be broadly classified into a carnivorous group possessing asymmetrical maxillae and producing no sheath material, and a phytophagous group whose members have symmetrical maxillae and produce sheath material. Although a few pentatomids of the second group have acquired the carnivorous habit, they have retained the same feeding methods as the phytophagous species.

At least two families, however, occupy an intermediate position with respect to feeding mechanisms. Members of these families, of which the Miridae is typical, may be either carnivorous or phytophagous in habit. They produce no sheath material, but have mouthparts characteristic of those of the phytophagous group. It is suggested that the sheath-material of the phytophagous species ensures the efficiency of the feeding process by minimizing loss of salivary liquids and plant juices during feeding. According to this theory, mirids are inefficient phytophagous feeders, and in particular, would lose salivary secretion within the plant. This may partly explain the phytotoxic effects for which these insects are notorious.

(3) Insect Biochemistry

(a) *Oxidase Activity in the Saliva of Plant-feeding Bugs.*

(Dr. P. W. Miles)

In all plant-feeding bugs so far examined either the principal salivary duct, the accessory salivary gland, or both, are the source of a polyphenol oxidase. In those species in which the enzyme is produced in the accessory gland, the ejected watery saliva shows appreciable oxidase activity. This phenomenon is being studied from the aspect of possible enzyme interference with growth regulation in plant cells.

(b) *Composition and Chemistry of Formation of Sheath-material of Plant-feeding Bugs.*

(Dr. P. W. Miles)

A lipid fraction of sheath-material, hitherto only suspected to be present, was isolated both from sheath-material and its precursor in the salivary glands

of a pentatomid, *Eumecopus* sp. The lipid proved to be mainly phospho-lipid, but other uncharacterized fractions were separated chromatographically.

It was established that the sheath precursor contained a large number of free sulphydryl groups and had a low redox potential; the sheath-material contained fewer sulphydryl groups and had a higher redox potential. From experiments on swelling and solubility of both precursor and emitted material, it was concluded that the structural stability of sheath-material resides in both inter-molecular hydrogen, and intra-molecular disulphide bonding, but that the gelling of the material into a compact mass in aqueous media is due to the formation of a relatively small number of co-valent inter-molecular links at the moment of ejection. In view of the presence of a polyphenol oxidase in the salivary apparatus, and of phenolic substances in the salivary secretions, it appears that co-valent linkages are formed by quinones produced by the action of the oxidase on a phenolic substrate. Such a substrate is being sought.

(4) Forest Entomology

(a) *Innate Capacity for Increase in* Ips grandicollis *Eichh.* (*Scolytidae*).

(Dr. F. D. Morgan)

Studies of progressive maturation of oocytes indicates that females are capable of laying many more eggs than has previously been thought. Females commencing oviposition rapidly reach a peak of some five or six eggs daily and maintain this rate indefinitely so long as conditions of site and temperature are favourable. At least some females overwinter and survive to produce more eggs in the second year.

(b) *Biology and Ecology of* Chlenias *spp.* (*Boarmiidae*).

(Dr. F. D. Morgan and Mr. N. C. Stewart)

Three species of *Chlenias* are responsible for major damage in pine forests of South Australia and Victoria. In addition, a further eight species in other genera, at present in insignificant numbers, have been discovered. Studies of the biology and ecology of this complex are in progress.

(c) *Biological Control of* Chlenias *spp.*

(Dr. F. D. Morgan, Mr. N. C. Stewart and Dr. J. H. Warcup (Plant Pathology Department))

Larvae of *Chlenias* spp. are subject to disease produced by a fungal-bacteria-virus complex. In some areas the fungus, *Entomophthora* sp., is the major pathogen; in others, a gram-negative bacterium causes local mortality in the population. Virus has also been found in dying and dead larvae.

In addition, the larvae are parasitized by a wide range of Hymenoptera, of which many species belong to the Braconidae.

Attempts are being made to assess the relative importance of these agents in the natural control of *Chlenias* populations.

(5) Apiculture

(a) *Lucerne Pollination.*

(Mr. K. M. Doull)

Studies on the pollination of lucerne have been continued. A sampling method for estimating the degree of cross-pollination has been developed, and will be used in future studies of honeybee behaviour in lucerne seed crops.

Two species of native solitary bees, *Nomia australica* Sm. and *Nomia flavoviridis* Cock'l., have been found to work lucerne, and preliminary studies on their biology have been made.

(b) *The Biology of* Nosema apis *Zander.*

(Mr. K. M. Doull)

It has been shown that most colonies carry light infections of *Nosema apis.* While conditions remain favourable, the parasite remains at a low population level, both in the hives and in infected bees. Should the bees be subjected to conditions of stress, the rate of multiplication of the parasite increases and an epizootic of *Nosema* disease may occur. Further studies are aimed at determining the factors which affect the multiplication of the parasite.

(c) *Bee Nutrition.*

(Mr. K. M. Doull)

The native flora of Australia produces both pollens and nectars which are apparently of low biological quality for honeybees. A preliminary study has been made of the relationship between "paralysis" of young bees and some native pollens.

(6) Insect Taxonomy

(a) *Taxonomy of Coccoidea with Special Reference to Pseudococcidae.*

(Miss Helen M. Brookes)

The distribution of *Quadraspidiotus perniciosus* in South Australia has been investigated. A morphological study of all stages of the species of *Quadraspidiotus* known to infest pome fruits in Australia has been made, and a key prepared for distinguishing the immature stages of those species.

Taxonomic studies on species of the Australian genus, *Epicoccus,* have continued. The number of species is much greater than has been recorded in the literature. In the past there has been some confusion between the genera *Epicoccus* and *Rhizococcus.*

Surveys of coccids producing leaf or stem galls on *Eucalyptus* spp. have continued, and considerable additions have been made to the list.

(b) *Taxonomy and Biology of* Diptera acalyptrata.

(Mr. H. F. Lower)

Studies of Tephritidae, Otitidae, and Sciomyzidae are continuing. Modern methods of trapping insects have revealed a fauna of these families in South Australia much more extensive, both in species and individuals, than has hitherto been known. The present studies will lead to a greater understanding of the distribution of these families in South Australia, and their relations to populations in other parts of Australia.

(7) Biological Control

(a) *Ecology and Biology of Arthropods Parasitic on* Oxalis per-caprae *L. and Allied Species of* Oxalis

(Mr. H. F. Lower)

A survey of insects and other arthropods feeding on *Oxalis pes-caprae* L. and allied species having a high oxalic-acid content is to be undertaken during 1962. The survey will be made in South Africa, in which area occurs the greatest number of endemic *Oxalic* species and will be an initial step in the programme.

3. General

A survey of the citrus-growing areas of South Australia, New South Wales and Victoria has been conducted to obtain first-hand information on the distribution and incidence of the red citrus-scale, *Aonidiella aurantii* (Mask.) and the yellow citrus-scale, *A. citrina* (Coq.).

Surveys of the forest-areas of South Australia, Victoria and Tasmania have been made to obtain information on the conditions which favour the wood-boring wasp, *Sirex*. In Tasmania and on the mainland, measures for its control or eradication have been devised and a programme of research commenced.

Plant Pathology

The Third Conference of the Australian Plant Pathologists was held at the Institute from October 16 to 20, 1961. The Conference was attended by approximately ninety delegates representing all the Australian States and New Zealand, and including overseas visitors from England and the United States of America. It took the form of Symposia which reviewed the recent advances in investigation of fungus diseases, virus diseases, nemotode diseases, disease resistance, disease inhibitors and plant quarantine. Specific diseases were cited freely in discussion and one session towards the end of the Conference was devoted to papers dealing with specific diseases.

1. Advisory Services.

The appointment of a Systematic Mycologist and a Forest Pathologist in 1960 and a second Virologist in 1961, has considerably strengthened these services and the Department is now able to cover the major fields of plant disease occurrence in South Australia.

In these services close co-operation is maintained with the State Departments of Agriculture and Woods & Forests and other State authorities through the identification of diseases, field surveys and the furnishing of information or advice on disease prevention and control. The State Departments readily supply detailed information through District Advisers on the occurrence of diseases, drawing attention to urgent problems which should be investigated and subsequently co-operating in many of the investigations. The co-operation is enhanced by the State Department of Agriculture permitting two of its cadets to undertake post-graduate training in this Department.

The following summary of disease incidence during 1960-61 includes only new diseases or those which were unusually severe.

In cereal crops the virus disease, barley yellow dwarf, was positively identified for the first time in 1960, following a visit by Dr. J. Slykhuis of the Canadian Department of Agriculture. The disease is widespread in South Australia and has undoubtedly been present for some time. Cereal root rots were commonly identified from the major cereal growing areas and in 1960 cereal eelworm, *Heterodera avenae*, caused such severe damage in parts of the Mid-North district that a number of crops were resown. In many of these cases the resown crops resulted in average yields, the remainder failing again because of nematode infestation.

Powdery mildew, *Erysiphe graminis*, was unusually severe on cereals, particularly barley; frost damage was also unusually severe in 1961.

A potentially serious virus disease, clover stunt, was common over many areas of South Australia in both 1960 and 1961. Widespread death of young subterranean clover stands in patches was due to attack of the roots by *Pythium.*

A co-operative survey with the Department of Agriculture of cherry trees in the Adelaide Hills has revealed that more than ninety per cent. of the best trees are virus-infested. The most common virus is necrotic ring spot; other virus diseases are not yet satisfactorily identified. Apparently virus-free trees of several of the main cherry varieties have been located for future propagating material. Supplies of virus-free cherry root stocks have been imported also for future propagation work. The Department has continued to screen importations of vegetative stone fruit propagating material for Australia on behalf of the Commonwealth Department of Health. Nematode infestations, particularly *Meloidogyne,* of stone fruit trees and grape vines, continue to cause concern in the Murray irrigation areas.

White rot of onion due to *Sclerotium cepivorum* occurred in the Mount Gambier area in 1960. Gangrene of potatoes due to *Phoma foveata* caused serious losses in some lots of interstate seed potatoes and heat and drought necrosis, an uncommon physiological disease of potatoes, was severe in a number of crops in 1961.

Verticillium wilt in cauliflowers appears to be increasing in severity and a severe outbreak of onion yellow dwarf was recorded in 1961. Cauliflower mosaic and a virus disease of lettuce thought previously to be tomato spotted wilt occurred widely in the vegetable areas near Adelaide and are causing considerable losses.

White rust of *Gerbera* caused by *Albugo candida,* first recorded in South Australia in early 1960, has caused serious damage to Gerberas.

Damping-off in forest nurseries due to a variety of fungi and graft failure in pines due to *Diplodia pinea* were again serious problems.

Dr. K. F. Baker, of the University of California, who spent 1961 in this Department, actively contributed to the Advisory Services, particularly in relation to propagation of nursery stock, his advice being sought by many interstate and local nurserymen.

2. Legume Inoculation Service.

(Dr. J. H. Warcup and Mr. S. R. Hockley)

The legume inoculation service, commenced by the Division of Soils, C.S.I.R.O., in 1938, and taken over by the Waite Institute in 1950, was terminated at the end of 1960. At the time the service was commenced no other source of cultures of nodule bacteria was available to farmers in South Australia. More recently commercial firms have supplied cultures throughout Australia and these cultures have been widely used in the State, in fact, sale of commercial cultures in recent years has exceeded distribution from the Waite Institute.

Over the past 11 years a total of over 35,000 cultures have been distributed to South Australian farmers from the Waite Institute. The service has proved of great value to the State for, in many instances, inoculation has meant the difference between success and failure in the establishment of important pasture plants, particularly lucerne.

Some investigational work on *Rhizobium* is continuing.

3. Research.

(a) *Pellicularia Investigations.*

(Dr. N. T. Flentje, Dr. A. Kerr, Mr. R. L. Dodman, and Miss Helena M. Stretton)

Studies on the number and distribution of nuclei and their behaviour during growth have been extended to cover the formation of basidia and basidiospores and the germination of the latter. As a preliminary to basidial formation the number of nuclei per cell is reduced to two, which fuse in the basidium and redivide twice to give four, each of which migrates through the sterigmata to give one nucleus per spore. There are a number of exceptions, however, which may have an important bearing on subsequent studies of the heterothallic or homothallic nature of different strains and attempts to form hybrids between them.

The behaviour of nuclei and their distribution in the formation of infection cushions by the fungus on a host plant has been studied.

Studies of the active materials present in host exudates which stimulate the formation of infection cushions have been seriously handicapped by the irregularity of results from the bio-assay methods.

It was discovered that single basidiospore cultures of pathogenic strains when grown on thin collodion membranes placed over an appropriate host seedling freely formed infection cushions on the membrane opposite the seedling and subsequently penetrated both the membrane and the seedling. This was the first direct demonstration of a diffusable material from the host exciting infection cushion formation. From this a new bio-assay technique has been developed using single basidiospore cultures of the different strains, thus removing some of the variation stemming from the heterocaryotic nature of the naturally occurring isolates, and growing them over collodion membranes with the materials being assayed on the other side of the membrane. This approach has yielded more consistent results.

Preliminary studies have been made of the variability of naturally occurring strains of the fungus using single cell or single basidiospore cultures from the parent strains and attempting to hybridize them.

(b) *Fusarium Wilt of Peas.*

(i) *Fusarium* Wilt Resistance in Peas (Mr. M. V. Carter).

A line of the variety Greenfeast, resistant to race 2 of *F. oxysporum f. pisi*, is being increased prior to field testing: to date it has been possible to retain the desired resistance acquired from the donor parent together with the desired agronomic characters of the recurrent parent variety. The parallel programme with the variety Victory Freezer has reached the stage of selecting a homozygous resistant line following selfing the fourth backcross. The variety Kelvedon Wonder (syn. William Massey) has been introduced into the breeding programme, and has reached the first backcross generation.

(ii) Soil-borne Pea Diseases (Dr. A. Kerr).

For a number of years *Fusarium* wilt of peas caused by *F. oxysporum f. pisi* race 2 has been an important disease in the River Murray Irrigation Settlements. When pea varieties resistant to wilt are grown, however, growth and yield are unsatisfactory, indicating that other pathogens may also be important. It has been shown that at least two other fungal pathogens, *F. solani* and *Pythium* sp.,

are involved. Selective media have been developed for measuring the populations of the three pathogens in virgin soils and in soils cropped with peas. The population of *F. oxysporum* and *F. solani* was 5-10 times higher, and that of *Pythium* sp. 20 times higher in soil cropped with peas for five consecutive years than in virgin soil. The importance of *Pythium* sp. was demonstrated by using Dexon which inhibits *Pythium* but not *Fusarium*. In pot experiments peas grown in Dexon-treated soil yielded 2-3 times higher than those grown in untreated soil.

(c) *Verticillium Wilt of Stone Fruits.*

(Dr. N. T. Flentje, Dr. J. H. Warcup and Mr. J. B. Taylor)

When uninjured apricot roots and spores of *Verticillium albo-atrum* are incubated together in a closed chamber, spore germination of the fungus is inhibited. Spores of *V. albo-atrum* are not affected by the presence of apple or tomato roots. An ether-extract from the bark of mature apricot roots similarly inhibited spore germination of *V. albo-atrum* and it was shown that mandelonitrile (MN) was present in the extract. MN is not directly responsible for the inhibition but is broken down into hydrogen cyanide which is strongly inhibitory and benzaldehyde which is a mild inhibitor. MN breaks down slowly by hydrolysis and rapidly in the presence of oxynitrilase enzymes which are present in *V. albo-atrum*.

Isolations made at monthly intervals from infected apricot trees confirmed earlier work that *Verticillium* could not be isolated between January-June.

(d) *Ascochyta Diseases of Peas.*

(Mr. M. V. Carter, Dr. A. Kerr and Mr. B. H. Pratt)

The dispersal and deposition of ascospores of *Mycosphaerella pinodes* from a long strip source and from a small field plot have been studied. Continuous sampling of air-borne ascospores within a field plot for a period of seven weeks showed that when regular nightly dews occur, ascospore release may continue for at least five nights after cessation of rain. On rainless days, there was a strong diurnal periodicity of air-borne spores at 15 cm. a.g.l., with a well-defined peak in the late afternoon, prior to the onset of dew.

Preliminary investigations of the efficiency of aerated steam treatment of pea seed for elimination of internally-borne *Ascochyta* fungi have shown that these fungi may survive treatment at 150° F. for 30 min., but that this treatment does not significantly reduce the seed germination.

Detailed spore-trapping during two growing seasons in irrigated pea fields has confirmed earlier data on the distribution of ascosporic inoculum of *M. pinodes*. There was a slow rise in ascospore number in the early stages of the crop, presumably from perithecia in debris from the previous crop. Later in the season a very rapid rise in number occurred, coinciding with the period of ascospore release from newly-developed perithecia in the growing crop.

A series of fungicides was screened and tested in the glasshouse and in the field. Bordeaux mixture appears to be the most promising.

Survival of *M. pinodes* in debris from an infected pea crop has been studied. It was found that ascospore ejection from infected pea straw dropped to a low level after straw had been buried for a few days, and that ascospores within buried perithecia were transformed to a form resembling chlamydospores. A small percentage of these forms germinated rapidly in distilled water and were

capable of initiating infection. The survival value of these chlamydospore-forms is not known.

(e) *Studies on Parsnip Canker.*

(Dr. A. Kerr and Mr. P. G. Hicks)

A survey of parsnip crops in the Adelaide area was carried out to assess the incidence of parsnip canker. Two main types were noted in some Hills crops; a highly pathogenic *Phoma* sp. was consistently isolated from samples of black lesions with even margins; other samples were of brown to black, shallower lesions of uneven depth. From the latter lesions four fungi were commonly isolated: *Itersonilia perplexans* (66 per cent.), *Cephalosporium* sp. (33 per cent.), *Phoma* sp. (23 per cent.), and *Fusarium oxysporum* (14 per cent.). Only *Phoma* was consistently pathogenic and the importance of the other three fungi is not known.

(f) *Diseases of Forest Nurseries.*

(Dr. O. Vaartaja)

The diseases studied were primarily damping-off of young *Pinus radiata* and *P. pinaster* seedlings in forest nurseries. To a lesser degree root rots of older seedlings were studied, and some work was done on other tree species. Samples of diseased seedlings and soil were collected from 15 nurseries. In all cases the disease appeared to be caused primarily by virulent soil-borne fungi. The incidence of these and associated fungi in all serious epidemics during the year was recorded. Representatives of various fungi were obtained in pure culture and stored for further studies. The collection now contains about 800 isolates. Many have been identified. The pathogenic potentials of about 50 representative isolates have been determined. Isolates of *Pythium irregulare* and *P. ultimum* seem to be the main pathogens, however, *Rhizoctonia solani* appeared to be of importance in some epidemics. Attempts to control disease with ten different seed treatments were made in four nurseries. Unfortunately little disease occurred at these sites.

(g) *Studies on the Microflora of South Australian Soils.*

(i) Activity of Fungi in Wheatfield Soil.

(Dr. J. H. Warcup)

Studies on the occurrence of fungi on wheat roots are being continued until two complete cycles of growth and decomposition are completed. Work was interrupted in 1960 because of a heavy weed infestation of the field. To prevent these seeding, the crop was ploughed in. This allowed prolific development of fungi on the decomposing residues and gave interesting data on fungal activity in soils.

(ii) Identity of Non-sporing Fungi Isolated from Soil.

(Dr. J. H. Warcup and Dr. P. H. B. Talbot)

Many fungi isolated from soil do not sporulate readily on agar media. Studies on methods of inducing fruiting and on identity of these fungi are being undertaken. Some twenty Basidiomycetes have been identified.

(h) *Influence of Temperature on Survival of Plant Pathogens.*

(Dr. K. F. Baker)

Dr. K. F. Baker of the University of California was a Fulbright visitor in the Department in 1961. He has developed the use of air-stream mixtures in

different proportions for treating at different temperatures material contaminated by plant pathogenic organisms. He collaborated with a number of people in the Department to investigate the survival of naturally occurring micro-organisms in Waite red-brown loam treated at different temperatures for half an hour. Various pathogenic fungi were then added to the treated soil and their survival in competition with the residual micro-organisms was studied in an attempt to find micro-organisms antagonistic to the pathogens.

(i) *Mycology.*

(Dr. P. H. B. Talbot)

Progress on the compilation of a check-list of South Australian Plant Diseases has been made. The work has reached the stage where the preliminary draft is being typed for circulation to colleagues for comment and additions.

Professor J. B. Cleland has continued to hand over his collections of fungi for incorporation in the Herbarium. In the past fifteen months some 1,700 specimens have been entered in the Herbarium. Professor Cleland has also donated a most valuable collection of original watercolour paintings of Agaricaceae and other large fungi of Australia. Specimens from the Herbarium have been loaned to different authorities and further collections received; most of the specimens received have required determination.

Work has begun on photo-copying good illustrations of Fungi Imperfecti in order to make a pictorial index of their genera for use in the Plant Pathology Department.

(j) *Morphogenesis in Fungi.*

(Mr. B. G. Clare)

The physiology and biochemistry of morphogenesis in *Pullularia pullulans* is being investigated. This organism is being used because it exhibits three distinct forms, a filamentous form bearing blastospores, a sterile filamentous form and a unicellular, yeast-like form. A comparison of the ultrastructures of the different forms is being made and experimental transformations from one form to another are being attempted. The rôles of protein-disulphide reductase, nucleotides and nucleic acids in these transformations are being examined.

(k) *Virus Investigations.*

(i) Stone Fruit Virus Investigations.

(Dr. N. C. Crowley)

Surveys carried out jointly with officers of the Department of Agriculture have revealed that almost 90 per cent. of the best cherry trees of the most important varieties are infected with necrotic ringspot virus. The survey is now being carried out on a broader basis to locate the virus-free trees of all the main cherry varieties grown in the State. Virus-free trees of six of the eleven main varieties have so far been located. Identification of other viruses affecting cherry trees is in progress.

(ii) Virus Diseases of *Brassica* Crops.

(Dr. N. C. Crowley and Mr. J. W. Randles)

A preliminary study of the ecology of the virus diseases of *Brassica* crops was carried out during 1961. Only one virus disease, caused by cauliflower

mosaic virus, was found to be of commercial importance. Incidence of the disease was found to be greatest during the autumn in crops grown in the Adelaide Hills, and during the winter in crops grown on the plains. The periods of the year when the spread of the disease was found to be most rapid corresponded with the periods of greatest activity of the aphid vectors *Myzus persicae* and *Brevicoryne brassicae*, as determined by data obtained from yellow water traps. It is suggested that the absence of symptoms of the disease during mid-summer months is due to temperature masking of symptoms.

Field investigation of the possibility of controlling the spread of the disease in seed beds, either by the use of various insecticides or of barrier crops, showed a very significant reduction of infection could be obtained by the use of a barrier crop of barley. None of the insecticidal treatments used were found to be of value.

(iii) General Virus Studies

(Dr. N. C. Crowley)

The rarity of seed transmission amongst plant viruses can be explained either by the inability of plant viruses to infect the meristematic tissues of their hosts, or by their inability to infect haploid pollen and egg cells. Present studies were aimed at determining with each of three virus diseases, which of these explanations is applicable. The time at which common bean mosaic virus infects bean embryos is being determined. Studies are also being carried out with both soybean and tomato to determine whether a virus which is not seed-borne will be seed transmitted in a tetraploid.

Studies are continuing on the multiplication of tobacco mosaic virus (TMV) in tomato root meristems. The concentration of virus in this tissue can be increased as much as a thousandfold by growing the infected plants in the presence of EDTA. Present investigations are aimed at determining the effect of virus infection and EDTA on the physiology of the meristemic cells.

The co-operative work with Mr. R. J. Van Velsen on the properties and modes of transmission of the new virus disease, *Centrosema* mosaic virus, has continued. Attempts have been made to partially purify this virus and determine its morphology. Results indicate that *Centrosema* mosaic virus is a flexuous rod-shaped particle in excess of 500 mμ long.

(iv) Investigations of Virus Diseases of Grape Vines.

(Dr. R. I. B. Francki)

The work begun by Dr. N. C. Crowley in 1958 is continuing. It now appears that at least four virus diseases of vines occur in South Australia. These resemble "fanleaf", "yellow vein banding", "mosaic" and "yellow mosaic" described in California. At present it is difficult to produce definite evidence as to the identity of these diseases by orthodox methods since most of the classical vine indicator varieties are unavailable in South Australia. Endeavours are being made to transmit the suspected "fanleaf" and "yellow mosaic" viruses to herbaceous hosts in order to facilitate their partial purification and the production of antisera. It is hoped that this work will make possible exact comparisons with viruses causing similar diseases in other countries.

(v) General Studies.

(Dr. R. I. B. Francki)

From previous studies by Francki and Matthews in New Zealand, it was concluded that 2-thiouracil (2-TU) inhibits TMV multiplication, at least in part, by the analogue being incorporated into the virus ribonucleic acid and thus rendering the particles non-functional. At present in addition to further work on the action of 2-TU on TMV multiplication, other base analogues are under test.

Ever since TMV was first partially purified, workers have been interested in what constitutes the minimal infectious particle of this virus. In partially purified preparations examined with an electron microscope, virus rods are uniform in width (15-18 mμ) but occur in various lengths ranging from less than 50 mμ to over 1,000 mμ. Some believe that infective virus particles have a minimal length of about 300 mμ whereas it has also been suggested that shorter rods may carry infectivity. This question is being investigated.

(l) *Nematology Investigations.*

(i) Root-knot of Stone Fruit.

(Mr. J. M. Fisher and Mr. J. F. Burdett)

Using a constant-environment cabinet, experiments were undertaken to determine the resistance of five peach varieties to attack by *Meloidogyne javanica.* Hosts were Fort Valley, Okinawa, S37 and Yunnan, imported from the U.S.A., and local Elberta. Five different nematode populations from Waikerie, Loveday, Berri, Renmark and Cooltong were used singly to inoculate all five peach varieties. Although development to the adult stage occurred in three Fort Valley and one Okinawa host, no egg production was observed in these two varieties; the remaining varieties supported egg production in all nematode populations except the one from Renmark which produced eggs only on Elberta.

Attempts to distinguish populations of *Meloidogyne* by chromosome number of the eggs proved unsuccessful. The diploid number of the populations was about 90.

(ii) Studies on the Pathogenicity of *Paratylenchus hamatus.*

(Mr. J. M. Fisher)

Populations of *Paratylenchus* have been followed for more than a year on apple roots in the Adelaide Hills. Counts of females, males and juveniles were taken. Strong correlation existed between the presence of apple roots in the soil and distribution of *Paratylenchus.* Variability from tree to tree was very great. Total populations of *Paratylenchus* except for a gradual decline in winter when apple roots were not growing showed little change over the year. However, there were significant changes in the number of adult females.

Whilst little economic damage to the trees was apparent from the attacks of the nematodes, root damage was shown by a change in the relation of nematode numbers to root weight. Males were always present in higher numbers than females, but by far the greatest numbers occurred as pre-adult non-feeding larvae.

(iii) Giant Cell Formation by *Meloidogyne.*

(Dr. A. F. Bird)

The development of giant cells induced by *Meloidogyne* in tomato roots has been followed under controlled growth conditions and the ultrastructure and histochemistry of these structures has been examined. Under sterile conditions normal giant cell development takes place. Giant cell development and maintenance appears to depend on a continuous stimulus from the nematode whose removal results in breakdown of the giant cell. A growth-promoting substance is present in galls, but not in adjacent roots.

Meteorological Records

Meteorological observations in connection with the work of the Waite Institute are being made at the Waite Institute itself. At Yudnapinna (50 miles north-west of Port Augusta) observations were made until January 1961, when they were taken over by the Bureau of Meteorology. Observations are made daily at 0900 local time. The records for 1960 and 1961, with climatological summaries, are given in Tables I to IV.

WAITE INSTITUTE (34° 58′S., 138° 38′E. *Height* 402 *ft.*)

Table I. Records for 1960 and 1961.

(*a*) *Monthly rainfall and evaporation, number of wet days, mean relative humidity, mean hours of bright sunshine per day, and mean solar radiation per day.*

Month	Rainfall (in.)		Number of days with ⩾0·04 in. rain		Evaporation (in.)		Relative humidity 0900 local time		Hours of bright sunshine per day		Solar radiation GM Cals/cm²/day	
	1960	1961	1960	1961	1960	1961	1960	1961	1960	1961	1960	1961
January	0·38	0·24	2	3	9·68	10·03	41	38	9·35	10·18	620·3	710·3
February	2·13	0·43	6	1	6·30	7·81	54	42	7·77	8·63	521·6	610·2
March	0·91	0·26	5	1	6·67	6·45	46	52	6·95	8·01	418·7	527·0
April	2·73	4·63	10	13	3·55	3·53	64	64	3·88	4·21	258·5	286·5
May	6·88	1·67	17	10	2·00	2·51	72	71	3·17	4·82	176·4	258·3
June	2·33	2·79	10	14	1·62	2·21	72	69	4·18	3·51	171·6	215·4
July	1·81	3·13	13	17	1·78	1·58	73	78	2·27	2·88	144·2	201·9
August	1·97	2·21	10	13	2·31	2·46	73	72	4·78	4·38	246·4	294·6
September	4·40	1·33	13	7	2·61	4·06	69	54	3·66	6·81	280·0	429·5
October	1·20	0·76	7	5	5·24	5·97	48	52	7·19	7·32	473·5	516·8
November	3·30	0·87	7	5	5·64	6·45	55	51	6·82	6·90	519·8	571·8
December	0·09	0·55	1	5	8·66	8·11	41	44	9·26	7·95	653·3	647·4
Year	28·13	18·87	101	94	56·06	61·17	59	57	5·77	6·30	373·7	439·1

(b) Mean of daily air temperatures; and extreme air temperatures

Month	Mean daily				Mean ½ (Max. + Min.)		Highest		Lowest	
	Maximum		Minimum							
	1960	1961	1960	1961	1960	1961	1960	1961	1960	1961
January	87·3	87·5	65·7	67·0	76·5	77·2	105·7	102·6	50·1	52·0
February	77·6	83·0	60·0	64·2	68·8	73·6	92·9	98·1	52·0	53·8
March	79·3	78·7	63·0	60·2	71·1	69·5	97·7	97·3	50·4	50·7
April	67·3	71·2	53·5	58·2	60·4	64·7	89·2	90·7	43·7	45·6
May	59·1	65·0	47·6	51·7	53·3	58·3	68·8	72·1	41·1	42·8
June	57·1	61·6	45·5	50·5	51·3	56·1	62·8	68·5	37·8	42·2
July	56·4	57·1	45·0	45·8	50·7	51·5	64·9	63·1	37·8	40·6
August	56·5	59·2	44·1	45·7	50·3	52·5	67·2	69·8	36·2	37·5
September	60·2	68·1	48·3	52·2	54·3	60·1	72·0	92·0*	42·5	44·2
October	70·3	72·9	52·6	54·5	61·5	63·7	88·1	92·9	44·1	43·0
November	68·6	74·4	51·2	56·8	59·9	65·6	88·4	99·0	42·4	47·1
December	83·2	80·0	62·4	58·9	72·8	69·5	101·0	102·5	47·3	46·8
Year	68·6	71·6	53·2	55·5	60·9	63·5	105·7	102·6	36·2	37·5

* Highest September Max. on record.

(c) *Mean of daily soil temperatures (°F) at 1 inch, 6 inches 12 inches and 24 inches.*

Month	1 in. Maximum		1 in. Minimum		6 in. Maximum		6 in. Minimum	
	1960	1961	1960	1961	1960	1961	1960	1961
January	111·5	113·8	65·5	66·5	88·4	88·5	73·4	74·5
February	97·7	108·7	61·0	63·9	80·7	85·9	68·4	72·2
March	97·1	103·2	61·5	60·2	79·5	81·4	67·9	68·4
April	78·6	77·5	52·6	55·7	66·9	68·8	59·3	61·7
May	63·0	70·5	45·8	49·2	56·1	62·1	51·0	55·1
June	60·5	64·4	42·6	47·6	53·1	57·9	47·8	52·7
July	57·4	60·5	42·4	44·1	50·4	54·1	46·1	49·1
August	62·2	65·2	43·7	44·5	54·9	56·6	49·1	49·9
September	66·5	79·6	47·9	50·4	58·8	66·2	52·5	56·0
October	84·2	91·1	52·9	55·1	69·8	74·3	59·2	61·9
November	87·6	95·7	52·8	58·5	72·3	78·3	60·3	65·3
December	107·8	103·4	63·5	61·0	84·4	82·2	70·3	68·7
Year	81·2	86·1	52·7	54·7	67·9	71·4	58·8	61·3

Month	12 in. Maximum		12 in. Minimum		24 in. Maximum		24 in. Minimum	
	1960	1961	1960	1961	1960	1961	1960	1961
January	80·3	80·5	75·2	75·8	72·7	72·9	71·9	72·2
February	75·1	78·8	71·0	74·1	70·5	72·5	69·7	71·7
March	73·7	74·8	70·0	70·4	69·2	69·4	68·6	68·8
April	64·2	66·0	61·7	63·7	63·3	64·7	62·8	64·2
May	54·3	58·8	52·7	56·8	54·5	58·1	54·1	57·7
June	51·2	55·3	49·8	53·9	51·4	55·1	51·2	54·8
July	49·1	51·6	47·8	50·2	48·9	51·4	48·6	51·1
August	51·3	53·0	49·5	51·1	50·1	51·8	49·8	51·5
September	55·1	60·1	53·2	57·2	52·9	56·2	52·5	55·6
October	63·7	67·7	60·2	63·5	58·6	62·1	57·8	61·3
November	66·1	71·5	62·0	66·8	61·2	65·2	60·4	64·2
December	75·7	74·5	70·9	70·1	67·6	67·9	66·9	67·2
Year	63·3	66·1	60·3	62·8	60·1	62·3	59·5	61·7

(d) *Mean wind speed at 1·25 metres, 2 metres, and 10 metres (miles per day)*

Month	1·25 metres		2 meters		10 meters	
	1960	1961	1960	1961	1960	1961
January	86·9	83·3	101·3	98·1	—	165·9
February	66·6	78·5	78·8	92·3	—	159·3
March	73·7	62·1	88·7	75·1	—	129·9
April	72·4	64·2	84·8	78·8	—	129·7
May	86·3	45·5	101·6	58·4	156·5	95·5
June	63·3	63·4	76·1	79·3	114·6	122·2
July	73·1	55·6	88·1	68·9	134·1	111·2
August	68·8	63·3	82·0	77·1	121·4	—
September	80·8	72·4	96·3	88·0	148·3	136·8
October	85·2	80·4	100·8	95·5	159·9	152·5
November	81·6	81·2	96·2	96·5	157·9	163·5
December	82·3	88·4	97·0	103·4	165·5	177·8
Year	76·7	69·9	91·0	84·3	—	—

Table II Climatological Summaries 1925-61

Month	Rainfall (ins.)	Days with ⩾0·04 in. rain	Evaporation (in.)*	Relative Humidity 0900 L.T.	Saturation deficit (ins. mercury) 0900 L.T.	Hours Bright sunshine per day	Solar Radiation (Gm cals/cm²/day)	Wind speed (miles per day)†	
								1·25 meters	2 meters
January	0·87	3·0	8·501	46	·429	9·11	684·9	86·1	99·9
February	1·07	3·1	6·905	50	·382	8·67	565·4	79·1	91·8
March	0·82	3·1	6·269	51	·350	7·66	474·1	74·3	86·9
April	2·16	7·6	3·861	60	·277	5·59	296·8	70·5	83·5
May	3·15	10·1	2·440	67	·155	4·13	225·3	65·1	77·9
June	3·02	11·3	1·703	74	·106	3·30	194·5	63·6	76·6
July	3·21	13·5	1·638	75	·091	3·18	171·5	66·1	80·0
August	2·88	12·4	2·233	70	·120	4·44	265·7	77·4	91·5
September	2·42	9·9	3·177	63	·173	5·64	352·3	77·0	92·3
October	2·14	9·1	4·530	58	·222	6·52	484·3	82·5	98·0
November	1·56	6·0	5·790	53	·296	7·68	555·4	83·0	98·4
December	1·14	4·7	7·415	48	·375	8·31	622·0	84·1	99·1
Year	24·44	93·6	54·462	60	·244	6·19	407·7	75·7	89·7

*Mean for 1935-61.

†Mean for 1950-61.

Month	Air Temperatures (°F)						
	Average daily			Average Monthly		Extreme	
	Max.	Min.	Mean	Max.	Min.	Highest	Lowest
January	82·0	60·8	71·4	101·6	50·0	111·8	46·7
February	80·8	60·8	70·8	98·5	50·5	105·7	44·1
March	78·3	59·5	68·9	95·3	48·7	105·2	42·8
April	70·3	54·6	62·5	85·8	45·7	94·3	41·5
May	64·0	50·7	57·3	75·2	42·7	82·4	34·8
June	59·0	46·9	53·0	66·5	39·4	77·1	33·7
July	57·2	45·3	51·3	64·8	38·7	72·3	32·5
August	59·1	46·0	52·5	69·3	38·6	78·4	33·7
September	63·7	48·4	56·1	78·7	39·9	92·0	33·7
October	68·2	51·1	59·6	86·4	42·1	94·3	38·8
November	73·7	54·4	64·0	93·8	44·0	101·7	40·0
December	78·5	57·9	68·2	99·2	47·1	107·8	41·8
Year	69·6	53·0	61·3	103·6*	37·1*	111·8	32·5

*Average Annual Max. and Min.

Month	Soil Temperatures (°F) Average Daily							
	1 inch		6 inches		12 inches		24 inches	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
January	109·3	64·0	85·6	71·5	78·3	73·1	73·1	71·3
February	105·9	63·5	84·3	70·9	77·8	72·8	73·6	71·8
March	99·6	61·1	79·8	68·0	74·6	70·1	71·6	69·9
April	81·7	54·8	69·1	60·6	66·5	63·3	66·1	64·5
May	69·3	49·8	60·8	54·5	59·6	57·3	60·5	59·0
June	62·7	46·4	55·5	50·4	54·7	52·7	55·6	54·6
July	60·7	45·0	53·5	48·5	52·5	50·5	53·2	52·2
August	64·3	46·1	55·9	50·0	53·9	51·9	53·7	52·6
September	73·1	49·2	61·9	53·8	58·4	55·3	56·8	55·4
October	82·9	53·5	68·9	58·5	64·0	60·2	61·2	59·6
November	94·0	58·1	76·5	63·9	69·9	65·4	65·9	64·1
December	103·3	62·0	82·3	68·6	74·9	70·0	70·2	68·4
Year	83·9	54·5	69·5	59·9	65·4	61·9	63·5	61·9

YUDNAPINNA

(32° 8′S., 137° 10′ E., Height 435 ft.)

TABLE III

Records for 1960 *and* 1961

(a) Monthly rainfall (ins.), number of wet days and mean relative humidity.

Month	Rainfall		Number of days with ⩾0·04 inches of rain		Relative humidity (0900 local time)	
	1960	1961	1960	1961	1960	1961
January	1·43	0·26	3	1	34	28
February	0·78		2		46	
March	0·0		0		39	
April	0·40		4		56	
May	1·47		6		72	
June	0·69		5		72	
July	0·78		5		74	
August	0·98		5		66	
September	2·32		7		57	
October	0·07		1		35	
November	0·53		4		37	
December	0·21		1		31	
Year	9·66		43		52	

(b) Mean of daily air temperatures; and extreme air temperatures (°F).

Month	Mean Daily									
	Maximum		Minimum		½(Max.+Min.)		Highest		Lowest	
	1960	1961	1960	1961	1960	1961	1960	1961	1960	1961
January	97·6	96·4	68·5	68·4	83·0	82·4	119·2	107·0	56·5	53·8
February	88·2		63·9		76·0		106·2		56·2	
March	88·4		62·3		75·3		100·6		53·8	
April	74·1		52·9		63·5		89·9		38·0	
May	62·6		45·3		54·0		72·5		38·8	
June	59·5		41·3		50·4		66·0		32·6	
July	60·3		41·3		50·8		71·0		33·5	
August	62·1		39·9		51·0		74·8		34·0	
September	67·6		46·7		57·1		83·0		37·0	
October	81·0		50·5		65·7		98·2		41·5	
November	80·5		52·1		66·3		100·0		42·0	
December	92·1		63·7		77·9		106·0		54·0	
Year	76·2		52·4		64·3		119·2		32·6	

Table IV Climatological Summaries 1939-60

Month	Rainfall (ins.)	Days with ⩾0·04 in. rain	Evaporation (in.)*	Relative Humidity 0900 L.T.	Saturation deficit (ins. mercury) 0900 L.T.	Mean daily soil temperatures (°F)†			
						1 inch		12 inches	
						Max.	Min.	Max.	Min.
January	0·65	1·8	14·52	43	·509	114·8	66·7	90·8	79·7
February	0·96	2·1	11·48	47	·418	109·0	65·2	89·2	77·9
March	0·58	1·8	10·34	49	·370	104·5	60·5	85·8	74·7
April	0·49	2·1	6·69	58	·231	88·4	53·0	75·8	65·7
May	0·97	3·5	4·25	68	·138	76·6	47·3	67·4	57·6
June	0·92	3·9	2·61	76	·082	66·2	42·0	61·1	50·6
July	0·88	4·5	2·93	76	·078	66·9	40·8	58·5	47·9
August	0·68	3·8	4·09	67	·122	73·0	44·2	61·4	51·6
September	0·57	3·4	6·44	53	·223	84·0	49·9	68·4	58·2
October	0·84	3·5	8·81	47	·307	92·4	55·8	75·0	63·6
November	0·65	3·0	11·09	43	·399	102·4	61·1	81·9	69·9
December	0·71	2·3	13·19	40	·491	114·7	65·3	87·9	76·7
Year	8·90	35·7	96·44	56	·281	91·1	54·3	75·3	64·5

*Mean for 1939-54

†Mean for 1946-54.

Month	Air Temperatures (°F)							Wind speed (miles per day) at 2 metres†
	Mean Daily			Mean Monthly		Extreme		
	Max.	Min.	Average	Max.	Min.	Highest	Lowest	
January	92·3	63·8	78·0	109·5	53·5	119·2	39·2	167
February	89·6	63·4	76·5	105·3	53·9	111·4	48·8	166
March	85·8	59·2	72·4	99·4	48·7	108·8	40·5	130
April	76·0	52·1	64·0	91·5	42·5	98·7	36·0	102
May	68·4	46·5	57·4	81·5	36·4	88·2	27·3	79
June	62·7	41·8	52·2	71·8	32·3	77·6	24·0	76
July	61·2	39·5	50·3	70·9	30·9	79·0	21·4	77
August	65·4	41·3	53·3	78·1	32·8	87·8	26·4	93
September	71·8	45·3	58·6	87·2	35·9	96·8	28·8	111
October	77·4	50·8	64·0	95·4	40·1	106·0	35·5	118
November	83·9	56·0	69·9	102·1	44·7	110·6	40·3	133
December	89·2	60·3	74·7	106·9	49·5	114·0	35·0	141
Year	77·0	51·7	64·3	111·4*	29·7*	119·2	21·4	117

*Average Annual Max. and Min. Temperature

†Mean for 1951-54

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Records of Field Experimental Work

PERMANENT ROTATION EXPERIMENT, 1926-1961 (C1)

Effect of different crop rotations on the yield of wheat.

Variety of crop and seed rate per acre: Sepoy wheat (1926-34), Seewari (1935-47), Seewari 48 (1948-61), 80-90 lb; Early Burt oats, 60-70 lb; Prior barley 70-80 lb; White Brunswick peas, 120-150 lb; Wimmera rye-grass, 10-15 lb (1926-45), and Wimmera rye-grass, 3 lb+Fulghum oats, 40 lb (1946-61) on rotations wheat, pasture, fallow and wheat, oats, pasture, fallow; Wimmera rye-grass 3 lb+subterrenean clover, 6 lb on the rotations wheat, 2 years pasture and wheat, 2 years pasture, fallow; phalaris 3 lb+subterranean clover, 6 lb+lucerne, 1 lb+Wimmera rye-grass ½ lb on the rotations wheat, wheat, 4 years pasture and the permanent pasture.

Basal dressing of superphosphate, 187 lb per acre (1929-43), 94 lb per acre (1944-61).

Design: Unreplicated, but each course of each rotation is represented each year.

Area of each plot=1/7 acre (1926-37) 1/7.6 acre (1938-61).

TABLE 1.

MEAN YIELDS OF CROPS IN EACH ROTATION IN 1960 AND 1961, AND OVER THE DURATION OF THE EXPERIMENT. (FIGURES IN BRACKET INDICATE THE NUMBER OF YEARS FOR WHICH REPRESENTATIVE YIELDS ARE AVAILABLE).

1960	Grain, Bushels per acre				Total produce, cwt. per acre*				
Rotation	Wheat	Barley	Oats	Peas	Wheat	Barley	Oats	Peas	Pasture
Wheat, fallow	23·5	—	—	—	29·0	—	—	—	—
Wheat, peas	21·2	—	—	9·1	26·3	—	—	31·8	—
Wheat, barley, peas	32·9	46·9	—	13·6	40·5	46·0	—	36·5	—
Wheat, oats, fallow	26·9	—	48·3	—	36·3	—	27·3	—	—
Wheat, pasture, fallow	35·4	—	—	—	44·4	—	—	—	64·1
Wheat, 2 years pasture: 1st year	44·3	—	—	—	50·0	—	—	—	89·4
2nd year	—	—	—	—	—	—	—	—	77·1
Wheat, 2 years pasture, fallow: 1st year	49·0	—	—	—	58·8	—	—	—	107·9
2nd year	—	—	—	—	—	—	—	—	87·0
Wheat, oats, pasture, fallow	51·9	—	58·9	—	62·6	—	46·4	—	31·0
Wheat, wheat, 4 years pasture: 1st year	36·0	—	—	—	42·4	—	—	—	79·0
2nd year	30·2	—	—	—	58·6	—	—	—	68·2
3rd year	—	—	—	—	—	—	—	—	106·9
4th year	—	—	—	—	—	—	—	—	81·3
Wheat continuously	22·1	—	—	—	27·3	—	—	—	—
Permanent pasture	—	—	—	—	—	—	—	—	164·2

*Air-dry weights of harvested crops, oven-dry weights of forage crops.

TABLE 1 (*continued*).

MEAN YIELDS OF CROPS IN EACH ROTATION IN 1960 AND 1961, AND OVER THE DURATION OF THE EXPERIMENT. (FIGURES IN BRACKET INDICATE THE NUMBER OF YEARS FOR WHICH REPRESENTATIVE YIELDS ARE AVAILABLE).

1961	Grain, Bushels per acre				Total produce, cwt. per acre*				
Rotation	Wheat	Barley	Oats	Peas	Wheat	Barley	Oats	Peas	Pasture
Wheat, fallow	8·7	—	—	—	26·0	—	—	—	—
Wheat, peas	14·8	—	—	9·1	32·0	—	—	31·1	—
Wheat, barley, peas	23·5	28·2	—	11·3	41·9	29·0	—	27·0	—
Wheat, oats, fallow	13·4	—	9·0	—	35·8	—	14·4	—	—
Wheat, pasture, fallow	11·2	—	—	—	30·6	—	—	—	18·9
Wheat, 2 years pasture: 1st year	21·3	—	—	—	32·4	—	—	—	27·1
2nd year	—	—	—	—	—	—	—	—	85·9
Wheat, 2 years pasture fallow: 1st year	19·9	—	—	—	41·9	—	—	—	54·5
2nd year	—	—	—	—	—	—	—	—	111·5
Wheat, oats, pasture, fallow	20·6	—	31·8	—	43·5	—	33·9	—	35·8
Wheat, wheat, 4 years pasture: 1st year	18·6	—	—	—	31·9	—	—	—	44·2
2nd year	13·0	—	—	—	22·9	—	—	—	110·7
3rd year	—	—	—	—	—	—	—	—	114·9
4th year	—	—	—	—	—	—	—	—	89·0
Wheat continuously	6·0	—	—	—	15·3	—	—	—	—
Permanent Pasture	—	—	—	—	—	—	—	—	102·5

*Air-dry weights of harvested crops, oven-dry weights of forage crops.

TABLE 1 (*continued*).

MEAN YIELDS OF CROPS IN EACH ROTATION IN 1960 AND 1961, AND OVER THE DURATION OF THE EXPERIMENT. (FIGURES IN BRACKET INDICATE THE NUMBER OF YEARS FOR WHICH REPRESENTATIVE YIELDS ARE AVAILABLE).

Mean yield to 1961	Grain, Bushels per acre				Total produce, cwt. per acre*				
Rotation	Wheat	Barley	Oats	Peas	Wheat	Barley	Oats	Peas	Pasture
Wheat, fallow	29·2(36)	—	—	—	42·9(36)	—	—	—	—
Wheat, peas	22·6(36)	—	—	17·0(34)	32·8(36)	—	—	28·2(34)	—
Wheat, barley, peas	27·3(10)	23·2(10)	—	14·7(10)	33·9(10)	24·4(10)	—	28·6(10)	—
Wheat, oats, fallow	30·8(35)	—	33·1(35)	—	47·5(35)	—	32·6(35)	—	—
Wheat, pasture, fallow	35·6(35)	—	—	—	49·8(35)	—	—	—	26·8(34)
Wheat, 2 years pasture: 1st year	29·4(10)	—	—	—	36·3(10)	—	—	—	27·5(10)
2nd year	—	—	—	—	—	—	—	—	48·7(10)
Wheat, 2 years pasture, fallow: 1st year	35·4(10)	—	—	—	47·8(10)	—	—	—	49·4(10)
2nd year	—	—	—	—	—	—	—	—	72·2(9)
Wheat, oats, pasture, fallow	42·1(34)	—	43·7(34)	—	59·8(34)	—	40·4(34)	—	29·0(34)
Wheat, wheat, 4 years pasture: 1st year	20·1(10)	—	—	—	33·0(10)	—	—	—	43·0(8)
2nd year	15·9(9)	—	—	—	27·6(9)	—	—	—	71·5(8)
3rd year	—	—	—	—	—	—	—	—	80·1(8)
4th year	—	—	—	—	—	—	—	—	69·8(8)
Wheat continuously	12·4(36)	—	—	—	23·2(36)	—	—	—	—
Permanent pasture	—	—	—	—	—	—	—	—	99·6(10)

*Air-dry weights of harvested crops, oven-dry weights of forage crops.

TABLE 2.

YIELD AND BOTANICAL COMPOSITION OF PASTURE PLOTS 1960 AND 1961. (OVEN-DRY WEIGHTS, CWT. PER ACRE).

1960		Sown Species					Volunteer species		
Rotation	Total	W.R.G.	Sub. clover	Phalaris	Lucerne	Grazing oats	Annual legumes	Annual grass	Miscel-laneous
Wheat, pasture, fallow	64·1	1·1	—	—	—	62·2	—	—	·8
Wheat, 2 years pasture: 1st year	89·4	42·5	3·1	·4	—	—	—	28·2	15·2
2nd year	77·1	32·2	7·8	1·9	—	—	—	18·9	16·3
Wheat, 2 years pasture, fallow: 1st year	107·9	55·5	12·5	1·4	—	—	—	34·4	4·1
2nd year	87·0	33·1	28·3	—	—	—	—	15·4	10·2
Wheat, oats, pasture, fallow	31·0	1·4	—	—	—	28·4	·3	—	·9
Wheat, wheat, 4 years pasture: 1st year	79·0	·3	4·9	—	—	—	T	73·6	·2
2nd year	68·2	3·8	11·9	—	—	—	—	50·1	2·4
3rd year	106·9	1·6	2·4	18·4	—	—	—	69·1	15·4
4th year	81·3	1·7	T	37·4	·3	—	T	22·7	19·2
Permanent pasture	164·2	·5	T	10·6	5·5	—	T	72·6	75·0
1961									
Wheat, pasture, fallow	18·9	·3	—	—	—	18·6	T	—	T
Wheat, 2 years pasture: 1st year	27·1	6·0	4·4	—	—	—	1·7	5·3	9·7
2nd year	85·9	3·9	27·0	—	—	—	1·7	40·9	12·4
Wheat, 2 years pasture, fallow: 1st year	54·5	25·2	11·1	·3	—	—	1·4	12·4	4·1
2nd year	111·5	19·5	21·9	T	—	—	·8	61·2	8·1
Wheat, oats, pasture, fallow	35·8	·4	—	—	—	35·2	·2	—	—
Wheat, wheat, 4 years pasture: 1st year	44·2	5·0	10·4	·4	·4	—	T	22·5	5·5
2nd year	110·7	6·4	27·1	1·8	—	—	—	71·5	3·9
3rd year	114·9	9·8	36·3	T	·9	—	T	52·0	15·9
4th year	89·0	2·6	6·0	19·2	—	—	T	56·7	4·5
Permanent pasture	102·5	T	T	10·5	1·6	—	—	78·1	12·3